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ORIGIN AND CLASSIFICATION OF PEGMATITES[1]

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INTRODUCTION

HISTORY AND DEFINITION OF "PEGMATITE." The word "pegmatite" was coined originally by Haüy in the early years of the 19th century as a descriptive term applied to rocks with a graphic texture. According to Kemp[2] the word means "bound or cemented together in a framework." In 1849 "pegmatite" was used by Delesse[3] to designate a very coarse granite and gradually the use of the term was extended to include all types of exceptionally coarse plutonic rocks whether graphic or not. Bastin[4] has stated that the distinguishing feature of pegmatites is not coarseness but irregularity of grain. Although irregularity of grain size is undoubtedly a feature of pegmatites, all of the pegmatites observed by the writer contained some relatively large mineral grains. The writer defines pegmatite as *an intrusive holocrystalline rock composed essentially of rock-making minerals which are developed in part in individuals larger than the grains of the same minerals occurring in the normal plutonic equivalent.* Minerals not classified as rock-forming may also be present in coarse crystals. In rare cases, notably the cryolite pegmatite of southwest Greenland, the essential components are not rock-forming minerals and exception must be made to the definition.

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[1] Awarded the second prize in the Walker Natural History Prize competition, May, 1932.

[2] Kemp, J. F., The pegmatites: *Econ. Geol.*, **19**, p. 699, 1924.

[3] Williams, G. H., Origin of the Maryland pegmatites: *U. S. Geol. Survey, 15th Ann. Rept.*, p. 675, **1895**.

SHAPE AND SIZE OF PEGMATITES. Pegmatites exhibit such a variety of shapes that it is impossible to choose any one as characteristic. Many are tabular (similar to dikes and veins) with one fairly definite dimension. They may be horizontal, vertical, or between the two extremes in inclination. Other pegmatites are circular or elliptical in plan ("pipes") with the axis vertical or nearly so. In places these bodies are funnel shaped, as is the Etta pegmatite in the Black Hills. Still other pegmatites have the shape described by Adams and Barlow[5] as "splashes" and by Lehmann as "flammen." Aside from the shapes mentioned there are a host of pegmatites of such irregularity that no descriptive word can be applied to them. However, the writer has observed that most of the pegmatites which have been exploited for feldspar, mica, cassiterite or other commercial minerals are either tabular bodies with very moderate dip or vertical masses with circular or elliptical cross-section.

Thin tabular bodies of pegmatite conformable to the structure of an enclosing layered rock, such as a gneiss, are known as lit-par-lit injections. The amount of injected material may be so great that the original rock has become subordinate.[6] Although the tendency of such injections is to parallel the banding of the preexisting rocks, transverse offshoots are commonly present also. Gevers and Frommurze[7] examined 1,710 pegmatites in the Erongo area of Southwest Africa and found that 79 per cent of these were parallel to the strike of the schist while the remainder were transverse. A very common feature of pegmatites that are intruded into banded rock is a pinch and swell structure. Some "swells" or lenses have maximum widths of over 50 feet, but pinch laterally to a few feet or even disappear altogether.

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[4] Bastin, Edson S., Geology of the pegmatites and associated rocks of Maine, including feldspar, quartz, mica and gem deposits: *U. S. Geol. Survey, Bull.* **445**, p. 10, 1911.

[5] Adams, Frank D., and Barlow, Alfred E., Geology of the Haliburton and Bancroft areas, Province of Ontario: *Can. Geol. Survey, Memoir* No. **6**, p. 140, 1910.

[6] Keith, Arthur, Gaffney-Kings Mt. Folio, South and North Carolina: *U. S. Geol. Survey, Geol. Folio* **222**, p. 6, 1931.

Complete dimensions of pegmatites are very difficult to obtain, not only on account of their irregularity but also because they are rarely exposed in over two directions. As a general rule, the two dimensions traceable on the outcrop of a tabular pegmatite are finite. The width or thickness of the body is determined by the position of the hanging and foot walls. The length (distance along the strike) may not be much greater than the thickness, the pegmatite having either abrupt or tapering ends. Adams and Barlow[8] in the Haliburton and Bancroft areas of Ontario have noted pegmatites over 250 feet wide. One has an area of 3½ square miles, and the longest pegmatite dike is 4 miles long. According to George,[9] pegmatite dikes in the Archean rocks of the Alma district, Park County, Colorado, measure four hundred feet and more in the narrowest direction. Maitland[10] has described pegmatites in the Wodgina district of Western Australia which "vary from mere threads to veins over 500 feet in width." But greater than any of these is "a massive fringe of pegmatite up to 700 yards in breadth" that is mentioned by Harker[11] as occurring on the eastern highlands of Scotland. However, as the third dimension is not known this figure may not represent thickness.

The concept of pegmatites extending down into the earth for great distances cannot be accepted, since mining operations have uncovered a definite bottom in a number of localities. The down-

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[7] Gevers, T. W., and Frommurze, H. F., The tin-bearing pegmatites of the Erongo area, South-West Africa: *Trans. Geol. Soc. S. Africa,* **32** (for 1929), pp. 111–149, 1930. (Abs. *Min. Abstr.,* **4,** pp. 411–412; Annot. Bibliog. *Econ. Geology,* **3,** p. 424).

[8] Adams, Frank D., and Barlow, Alfred E., Geology of the Haliburton and Bancroft areas, Province of Ontario: *Can. Geol. Survey, Memoir* No. **6,** p. 141, 1910.

[9] George, R. D., Geology and ore deposits of the Alma district, Park County, Colorado: *Colo. Geol. Survey, Bull.* **3,** p. 46, 1912.

[10] Maitland, A. Gibb., Third report on the geological features and mineral resources of the Pilbara gold field: *West. Australia Geol. Survey, Bull.* **23,** p. 48, 1906.

[11] Harker, A., Natural history of igneous rocks, New York, p. 327, **1909.**

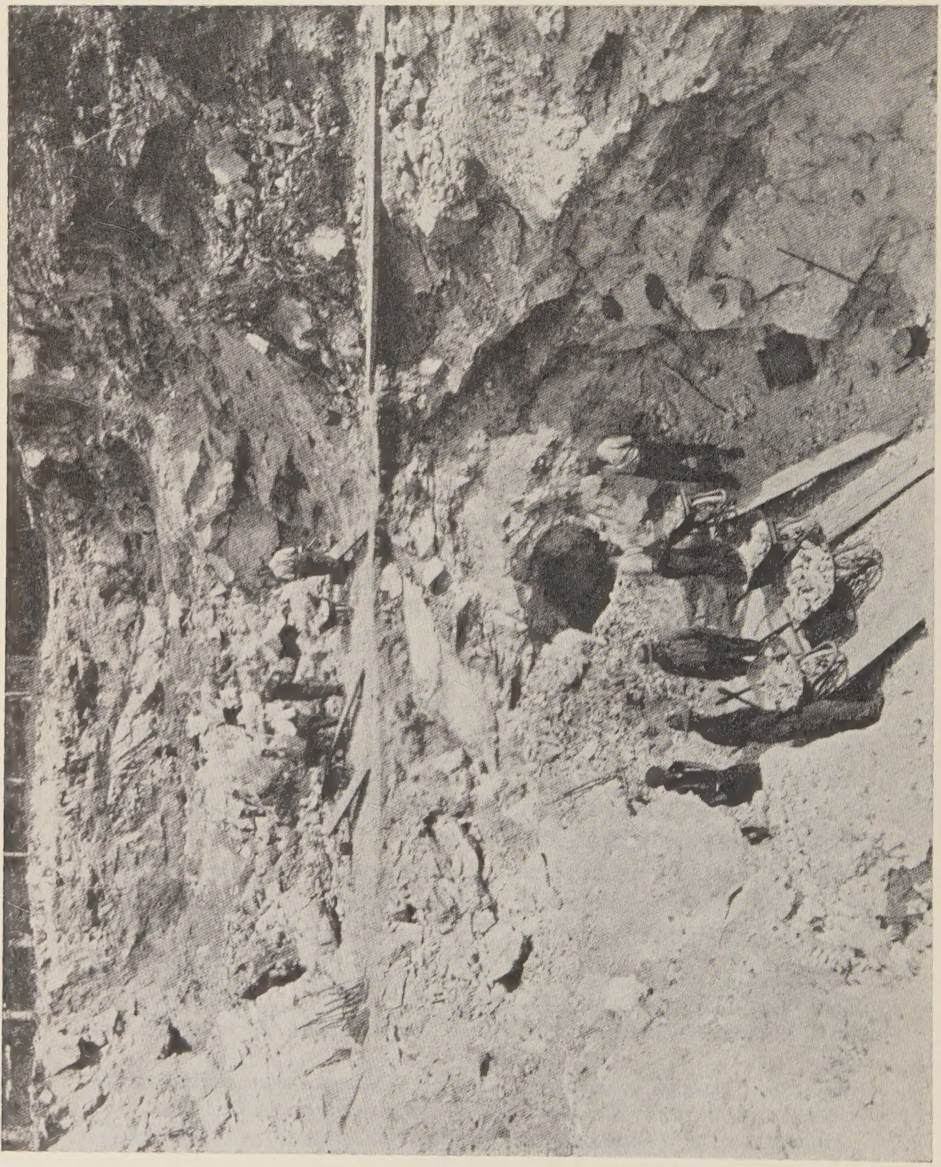

Fig. 1. Feldspar quarry, Buckfield, Maine, showing cavity uncovered during mining.

ward constriction of the Etta pegmatite has already been mentioned. Galpin[12] has noted in the Georgia pegmatites that although, due to the mountainous relief, it is possible to follow some pegmatites over a vertical range of several hundred feet, others pinch out within 20 or 30 feet. Similar observations have been made in the Amelia district in Virginia where a few pegmatites have been worked to a depth of 150 feet without reaching the bottom while others have played out entirely in 25 feet.[13] Keith[14]

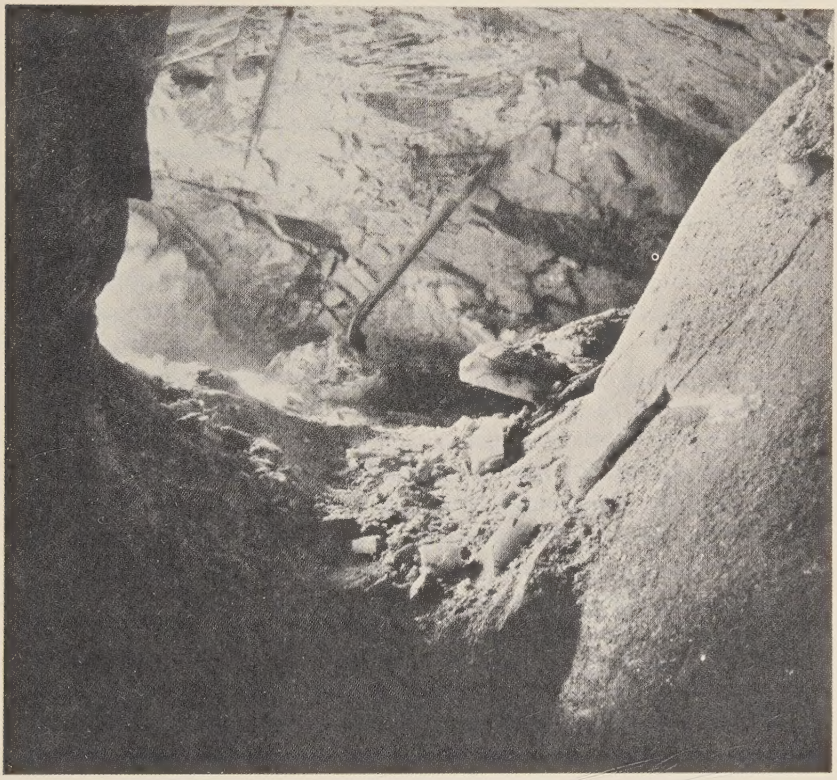

FIG. 2. View within pegmatite cavity, Buckfield, Maine.

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[12] Galpin, S. L., A preliminary report on the feldspar and mica deposits of Georgia: *Georgia Geol. Survey, Bull.* **30**, p. 22, 1915.

[13] Pegau, A. A., The pegmatites of the Amelia, Goochland, and Ridgeway areas, Virginia: *Amer. Jour. of Sci.* (5), **17**, p. 543, 1929.

[14] Keith, Arthur, Gaffney-Kings Mt. Folio, South and North Carolina: *U. S. Geol. Survey, Geol. Folio* **222**, p. 12, 1931.

describes a pegmatite dike in the Carolinas as follows: "This pegmatite dike ranged from a thin seam to a mass six feet in thickness; it had a length of about 40 feet and extended to a depth of about 20 feet. The whole dike was removed in mining, leaving only a seam in the hypersthenite to show where it had pinched out to the west and in the bottom."

CAVITIES. Open spaces ranging in size from very minute cavities to large caves are a characteristic feature of many pegmatites (Figs. I and II). Large openings have been found in the pegmatites of Madagascar, central Maine, Llano County, Texas, and San Diego County, California. On the other hand, cavities are almost unknown in the large pegmatite bodies in the Black Hills. Pegmatite cavities are invariably lined with vuggy crystals, often of gem quality. Formerly such openings were considered to be caused by local segregations of water in the pegmatite magma which escaped subsequent to the consolidation of the pegmatite. Now, however, it is believed that these cavities are due to an excess of solution over precipitation on the part of hydrothermal waters of pegmatitic origin.[15]

POSITION WITH RESPECT TO PARENT INTRUSIONS. Pegmatites are never found far from intrusive igneous rocks. Where a batholith is intruded into gneisses and schists, the adjacent country rock in most cases contains numerous pegmatite bodies. Those in Manitoba occur in roof pendants. Grout[16] in his studies of the Duluth gabbro has found pegmatites extending from the lower contact of the gabbro into the floor rock "to a distance equivalent to about 100 feet from the former position of the gabbro." Of greatest frequency is the occurrence of pegmatite in the laterally adjacent country rock. However, many pegmatite bodies occur entirely within what is probably the parent intrusive. In this case the contact between pegmatite and enclosing rock may be a gradational one.

CONTACT METAMORPHIC EFFECTS. Although the thickness of the zone of contact metamorphism produced by a pegmatite is not comparable in magnitude to that produced by a batholithic intrusion, the suite of minerals produced is often a much more interesting one, for there is not only reaction between the pegmatite magma and the country rock, but in the case of the complex pegmatites (to be more fully described in the chapters on origin and classification) hydrothermal solutions of unusual character are produced which may wander out into the adjacent rock and create there a unique assemblage of minerals. Pegmatite metamorphism at the contact is not only exomorphic but also endomorphic, for in many localities wall rock contamination has produced abnormal mineralization within the border of the pegmatite. Fersman[17] classifies pegmatites into three types: (1) normal, (2) contact pegmatites, where there has been some exchange of material, and (3) migmatic pegmatites, where migration has been even more pronounced, especially in the removal of volatile constituents from the pegmatite magma.

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[15] Landes, Kenneth K., The paragenesis of the granite pegmatites of central Maine: *Am. Mineralogist*, **10**, pp. 355–411, Nov. 1925. Hess, Frank L., The natural history of pegmatites: *Eng. & Mining Jour.-Press*, **120**, no. 8, pp. 289–298, Aug. 22, 1925. Palache, Charles, Davidson, S. C., and Goranson, E. A., The hiddenite deposit in Alexander County, North Carolina: *Am. Mineralogist*, **15**, pp. 280–302, 1930.

[16] Grout, F. F., The pegmatites of the Duluth gabbro: *Econ. Geol.*, **13**, p. 187, 1918.

As is to be expected, the greatest contact metamorphic effect takes place where pegmatitic magmas intrude limestone country rock. Nephelite-syenite pegmatites which have invaded limestone in Ontario contain sodalite, cancrinite, grossularite, nephelite, vesuvianite, and diopside in the contact zone.[18] The alkaline pegmatite of Magnet Cove, Arkansas, contains limestone inclusions in which mica, wollastonite, and thomsonite have formed.[19] Pegmatite dikes cutting limestone in Ferry County, Washington, have produced a garnet rock composed chiefly of andradite, albite and calcite within the limestone.[20] Newland[21] states that where pegmatitic invasions in the Adirondack area have reached limestone, contact metamorphic silicates and magnetite have been formed. Endomorphic action is well illustrated in Aberdeenshire, Scotland, where a coarse biotite pegmatite grades into a finer grained diopside-bearing rock where it traverses limestone bands. Diopside has also formed in the limestone. "There has thus been a reciprocal action, the pegmatite being enriched in lime and the limestone in silica."[22] Similar developments of diopside in pegmatite have been noted by Watson[23] in Howard County, Maryland, where a pegmatite magma is intruded along a dolomite-schist contact, and by Eskola[24] in western Massachusetts and Finland.

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[17] Fersman, A. E., Über die migmatischen pegmatite des Urals. (Abs. *Min. Abstr.*, **3**, p. 84).

[18] Osborne, F. F., The nepheline-gneiss complex in Dungannon Township, Ontario, Canada: *Amer. Jour. of Sci.*, (5), **20**, p. 48, 1930.

[19] Landes, K. K., A paragenetic classification of the Magnet Cove minerals: *Am. Mineralogist*, **16**, p. 325, 1931.

[20] McLaughlin, D. H., Copper sulphides in syenite and pegmatite dikes: *Econ. Geol.*, **14**, p. 406, 1919.

[21] Newland, D. H., Structures in Adirondack magnetites: *Bull. Geol. Soc. Amer.*, **42**, p. 238, 1931.

Neither have schists been immune to the metamorphosing action of intrusive pegmatites. Schwartz and Leonard[25] have noted that the schistosity of the country rock surrounding the Etta pegmatite in the Black Hills has been destroyed for a distance of 5 to 15 feet and the rock altered to one of grano-blastic texture. The contact minerals developed in this zone are feldspar, quartz, muscovite, tourmaline, apatite, zircon, and magnetite. Extensive tourmalinization of schist adjacent to pegmatite has been described in New Hampshire by Megathlin[26] and in Colorado by Patton.[27] Both garnet and tourmaline have been developed in the contact rocks in the Amelia area of Virginia.[28]

Although granite is much less susceptible to reaction and is less penetrable than limestone and schist, it also may contain an enrichment of unusual minerals adjacent to pegmatites. The cassiterite in the country rock surrounding the Zaiplaats tin pipes in the Bushveldt area of South Africa is an example. Also, the radial tourmaline groups in the Stone Mountain granite of Georgia described by Watson[29] probably were formed by solutions escaping from near-by pegmatites.

Of extreme interest to mineralogists is the contact metamorphism caused by the intrusion of pegmatites into the Franklin Furnace ore body which has been described by Ries and Bowen[30] and Palache.[31] According to Palache the pegmatite contact minerals include most of those peculiar to that locality. They are divided into two groups (a) those that are due to mere recrystallization under abnormal temperatures or to direct reaction between the ores and silica and alumina of the pegmatite, and (b) those which are very evidently derived entirely from the pegmatite magma.

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[22] Read, H. H., A diopside-bearing pegmatite near Ellon in Aberdeenshire: *Trans. Edinburgh Geol. Soc.*, **11**, pp. 353–356, 1925. (Abs. *Min. Abstr.*, **3**, p. 37).

[23] Watson, E. H., A diopside-bearing pegmatite in dolomite: *Econ. Geol.*, **24**, pp. 611–625, 1929.

[24] Eskola, Pentti, On contact phenomena between gneiss and limestone in western Massachusetts: *Jour. Geol.*, **30**, pp. 265–294, 1922.

[25] Schwartz, G. M., and Leonard, R. J., Contact action of pegmatite on schist: *Bull. Geol. Soc. Amer.*, **38**, No. 4, pp. 655–664, 1927.

[26] Megathlin, G. R., The pegmatite dikes of the Gilsum area, New Hampshire: *Econ. Geol.*, **24**, 2, pp. 163–181, 1929.

[27] Patton, H. B., Tourmaline and tourmaline schists from Belcher Hill, Colo.: *Bull. Geol. Soc. Amer.*, **10**, pp. 21–26, 1898.

[28] Pegau, A. A., The pegmatites of the Amelia, Goochland, and Ridgeway areas, Virginia: *Amer. Jour. Sci.*, (5), **17**, pp. 543–547, 1929.

[29] Watson, T. L., On the occurrence of aplite, pegmatite, and tourmaline bunches in the Stone Mountain granite of Georgia: *Jour. Geol.*, **10**, p. 193, 1902.

[30] Ries, H., and Bowen, W. C., Origin of the zinc ores of Sussex County, New Jersey: *Econ. Geol.*, **17**, pp. 517–571, 1922.

THEORIES OF ORIGIN

INTRODUCTION. The various theories which have been developed to account for the formation of pegmatites may be divided into two groups, aqueous and igneous. Included within the aqueous group are all of the theories in which near-by rocks rather than magmas are considered to be the source of the elements contained in the pegmatite minerals. Theories classified as igneous include all those in which the pegmatite minerals are considered to be of magmatic origin, either by direct crystallization, or by precipitation from hydrothermal solutions (attenuated magmas). Further subdivisions are made within each group.

The older theories of pegmatite origin have been reviewed in detail by a number of writers (Brögger,[32] Williams,[33] Crosby and Fuller,[34] Van Hise,[35] Spurr,[36] and Hastings[37]) between 1890 and 1908 so will be but briefly treated in this paper.

AQUEOUS THEORIES. The aqueous theories are divided into two groups, namely lateral secretion and selective solution. Lateral secretion, at one time very popular as applied to the genesis of ore veins, is now largely discarded for both ore veins and pegmatites. But the theory of selective solution still has many adherents when applied to the lit-par-lit pegmatites.

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[31] Palache, Charles, Paragenetic classification of the minerals of Franklin, N. J.: *Am. Mineralogist*, **14**, pp. 1–18, Jan. 1929.

[32] Brögger, W. C., Die Mineralien der Syenitpegmatitgänge der Südnorwegischen Augit-und Nephelinsyenite: *Zeit. Kryst. Min.*, **16**, 1890.

[33] Williams, G. H., Origin of the Maryland pegmatites: *U. S. Geol. Survey, 15th Ann. Rept.*, pp. 675–684, **1895**.

[34] Crosby, W. O., and Fuller, M. L., Origin of pegmatites: *Am. Geol.*, **19**, pp. 147–180, 1897.

[35] Van Hise, C. R., Treatise on metamorphism: *U. S. Geol. Survey, Monograph* **47**, 1904.

[36] Spurr, J. E., Ore deposits of the Silver Peak Quadrangle, Nevada: *U. S. Geol. Survey, Prof. Paper* **55**, 1905.

[37] Hastings, John B., Origin of pegmatites: *Am. Inst. Mining Engineers Trans.*, **39**, pp. 105–128, 1909.

1. *Lateral Secretion*

According to the lateral secretion theory the source of the elements is the surrounding rock and ground water is the medium of solution, transportation, and reprecipitation. Saussure is credited by Crosby and Fuller[38] as the original proponent of this theory. It was most strongly supported in the United States by T. Sterry Hunt and at the time of Williams' paper (1895) was the prevailing theory. Williams[39] himself believed that both segregation (aqueous) and intrusive pegmatites were present in the Maryland areas which he studied. Van Hise[40] in 1904 attempted to add an aqueous modification to the igneous hypothesis: "As the pegmatites close to the central mass solidify a large portion of the water is expelled and travels outward to help form the pegmatitic rocks having a more distinctive vein character; but in many and perhaps most cases the water in the outlying pegmatite dikes and veins which more and more assume the character of ordinary veins has been largely derived from the surrounding rocks."

2. *Selective Solution*

The essence of the selective solution theory is that rock minerals in the presence of interstitial water may, with increase in pressure and temperature, go into solution and later reprecipitate to form a rock igneous in appearance and pegmatitic in texture. If the rock is a layered one, some layers may go into solution more readily than others. This would explain the alternation in the lit-par-lit pegmatities of what is apparently igneous rock with metamorphic rock. The basic principles of the theory of selective solution have been expressed by a number of geologists. For example, in Williams' review[41] he outlines the views of Kalkowsky and Goodchild as follows: "Kalkowsky suggests that pegmatite might be formed through the melting of granulite material brought about by dynamic agencies; and Goodchild has proposed that lenses of pegmatite might be due to local fusion through the relief of pressure in rock masses which were potentially molten but kept in the solid state through pressure." In 1901 Julien[42] attributed the origin of pegmatites on Manhattan Island to molecular rearrangement of the material of the schist. Three years later Van Hise[43] described minute pegmatitic veins of quartz and feldspar in the Marquette district of Michigan. His monograph contains the following statement: "In this case it seems clear that pegmatization has taken place during the metamorphism of the rock in connection with mechanical action without the assistance of any extraneous igneous material, and is therefore essentially aqueous." Fenner[44] credits Sederholm with the belief that strata may become buried to sufficient depths as to become plastic in which case the more fusible portions will actually form a magma. The term "selective solution" was coined by Lane[45] in 1913 in a paper in which he states his belief that some of the Maine pegmatitic granites have this origin. Daly[46] is favorably impressed with this theory: "During intense regional metamorphism, especially that of the dynamic kind, deep-seated rocks charged with much interstitial water may reach the relatively low temperature at which minerals corresponding to the quartz-feldspar eutectic go into solution with the water and other volatile fluxes. Such small, locally generated pockets, lenses or tongues of fluid may be driven through the solid country rock for an indefinite distance; subsequently to crystallize with the composition and habit of the true batholithic derivatives. It is thus quite possible that these particular rocks, though truly magmatic, have had no direct connection with abyssal injections."

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[38] Crosby, W. O., and Fuller, M. L., Origin of pegmatites: *Am. Geol.*, **19**, p. 162, 1897.

[39] Williams, G. H., Origin of the Maryland pegmatites: *U. S. Geol. Survey, 15th Ann. Rept.*, p. 679, **1895**.

[40] Van Hise, C. R., Treatise on metamorphism: *U. S. Geol. Survey, Monograph* **47**, p. 728, 1904.

[41] Williams, G. H., Origin of the Maryland pegmatites: *U. S. Geol. Survey, 15th Ann. Rept.*, p. 678, **1895**.

Although the theory of selective solution is a very plausible one for some of the lit-par-lit pegmatites, the writer is not convinced that it is a correct solution of the problem. According to field evidence there is every gradation between the thin inter-bed pegmatites and the large lenses which contain minerals with a chemical composition (i.e. beryl) which precludes origin from local materials.

IGNEOUS THEORIES. There are three igneous theories: (1) pegmatites originate through crystallization of viscous magmas, (2) they originate through precipitation from highly attenuated magmas, and (3) the hydrothermal replacement theory, which is essentially a combination of the other two, involving two or more periods of formation ranging from magmatic to hydrothermal.

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[42] Julien, W. A., Notes on the origin of the pegmatites from Manhattan Island and from North Carolina: *N. Y. Acad. Sci. An.*, **13**, p. 507, 1901.

[43] Van Hise, C. R., Treatise on metamorphism: *U. S. Geol. Survey, Monograph* **47**, p. 725, 1904.

[44] Fenner, C. N., On the mode of formation of certain gneisses in the highlands of New Jersey: *Jour. Geol.*, **22**, p. 610, 1914.

[45] Lane, A. C., Origin of granites as well as metamorphic crystals by selective solutions: *Bull. Geol. Soc. Amer.*, **24**, p. 704, 1913.

[46] Daly, R. A., Igneous rocks and their origin, New York, p. 370, 1914.

1. Viscous Magma Theory

The viscous magma theory is the "igneous theories" classification of Crosby and Fuller.[47] According to them, Charpentier was the first to clearly describe pegmatite origin through igneous agencies. He was followed by De la Beche, Bronn, Fournet, Durocher, Angelot, and Naumann. The viscous magma concept soon gave way to the aqueous magma theory, but it had an interesting revival in a paper by Merritt[48] in 1923 on the function of colloids in pegmatitic growths. Merritt describes the formation in gels of spherically radiating crystals, such as are often found in pegmatites, and also states his belief that the presence of the large spodumenes in the Etta pegmatite signifies high viscosity of magma. However, both the spherically radiating crystals and the large spodumene "logs" are much better explained, in the writer's opinion, by the third igneous theory, that of hydrothermal replacement.

2. Aqueous Magma Theory

The evolution of the aqueous magma or "aqueo-igneous" theory is well presented by Crosby and Fuller.[49] According to this theory, pegmatites are formed by precipitation from the attenuated residual magma resulting from the crystallization of a batholith. It was first advanced by Elie de Beaumont, and it found extremely strong support in the writings of Lehman and Crosby and Fuller. The greatest supporter of the aqueo-igneous theory in recent years was J. F. Kemp.[50]

3. Hydrothermal Replacement Theory

The hydrothermal replacement theory involves both magmatic crystallization and the precipitation, usually through replacement, of material in solution in waters of magmatic origin. There have been three stages in the evolution of this theory: (1) a period of development, (2) the culmination in 1925 with the publication of several papers containing important evidence, and (3) a subsequent period of verification during which additional evidence has been gathered by a number of investigators. These three periods will be taken up in chronological order.

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[47] Crosby, W. O., and Fuller, M. L., Origin of pegmatites: *Am. Geol.*, **19**, p. 163, 1897.

[48] Merritt, C. A., The function of colloids in pegmatitic growths: *Roy. Soc. Canada, Proc. and Trans.*, 3d ser., **17**, sec. 4, pp. 61–68, May, 1923.

[49] Crosby, W. O., and Fuller, M. L., Origin of pegmatites: *Am. Geol.*, **19**, p. 166, 1897.

[50] Kemp, J. F., The pegmatites: *Econ. Geol.*, **19**, p. 712, 1924.

Apparently Brögger[51] was the first to recognize the formation of pegmatites in successive stages. His classic on the southern Norway alkaline pegmatites was published in 1890, 35 years before the theory which he initiated became very widely accepted. However, during that interval a number of geologists and mineralogists recognized that the history of pegmatites was a complex one and expressed a belief in hydrothermal activity. Thus, Waring[52] who described the pegmatite veins of San Diego County, California, in 1905 states: "Later a more aqueous magma was forced up through the reopened crevices and formed the upper portions of the vein." Bayley[53] in 1910 published a report describing magnetite in the pegmatites of the New Jersey highlands in which occur the following sentences: "The magnetite is thus in two generations, the first of which crystallized before any of the other constituents of the rock and the second after all of the others had been formed. . . . The later magnetite, which is in the nature of a subsequent enrichment, was evidently introduced after the normal components of the rock had crystallized . . . Very probably the vehicle of transportation was a hot aqueous solution or possibly a vapor which emanated from the same magmatic source as the material that produced the pegmatite . . . The channels through which the solutions circulated presumably afforded the most favorable opportunities for deposition of mineral matter, and such portions of the rock naturally became richer in magnetite than other portions through which the solutions slowly percolated, and thus became the ore shoots. In some places there may have been replacement of the silicates by magnetite, causing further enrichment of the mass. . . ."

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[51] Brögger, W. C., Die Mineralien der Syenitpegmatitgänge der südnorwegischen Augit-und Nephelinsyenite: *Zeit. Kryst. Min.*, **16**, 1890.

[52] Waring, G. A., The pegmatite veins of Pala, San Diego County, California: *Am. Geol.*, **35**, p. 366, 1905.

[53] Bayley, W. S., Iron mines and iron mining in New Jersey: *N. J. Survey Final Report*, **7**, pp. 150–151, 1910.

The possibility of a recurrence of pneumatolytic activity causing the development of cavities and the crystallization of aegirite and riebeckite in the pegmatites of Quincy, Mass., was mentioned by Warren and Palache[54] in 1911. In the same year Derby[55] described the mineralization of a gold-bearing lode of Passagem, Minas Geraes, Brazil, as occurring in three distinct processes. The first of these processes was the filling of a fissure with pegmatite. This was followed by fracturing and a second mineralization, which in Derby's opinion was possibly an after-effect of the granitic eruptions. The solutions active during the second stage precipitated tourmaline and sericitized the feldspar. During the third period of mineralization compounds of sulphur, arsenic, and the metals, including gold and silver, invaded the lode and probably also portions of the country rock.

Makinen[56] in 1913 described in considerable detail the pegmatites of Tammela, Finland, and the paragenesis of the pegmatite minerals. Two distinct periods of crystallization, one at temperatures above 575° C. and the second at lower temperatures, are recognized by Makinen. Brown tourmaline was formed during the earlier period and blue tourmaline during the later stage. There are similarly two generations of muscovite and quartz.

In two separate papers by Ziegler[57] published in 1914 a later phase of mineralization in the pegmatites of the southern Black Hills is mentioned. In one instance the replacement of pegmatite minerals by cassiterite is noted and the other paper describes deposition of amblygonite from solutions which rose through faulted and brecciated portions of the Peerless and Hugo pegmatites. In the same year Macdonald[58] described later cassiterite in the Bushveldt tin deposits in an article in which the following sentence appears: "The cassiterite is quite exceptionally found completely within the valencianite, and in such cases it is evident that the mineral has been introduced along cracks, and probably part of the feldspar has been replaced."

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[54] Warren, C. H., and Palache, Charles, The pegmatites of the riebeckite-aegirite granite of Quincy, Massachusetts, U. S. A.; their structure, minerals, and origin: *Am. Acad. Arts & Science Proc.*, **47**, p. 145, 1911.

[55] Derby, Orville A., On the mineralization of the gold-bearing lode of Passagem, Minas Geraes, Brazil: *Amer. Jour. Sci.*, 4th ser., **32**, pp. 185–190, 1911.

[56] Makinen, Eero, Die Granitpegmatite von Tammela in Finnland und ihre Minerale: *Commission Géologique de Finlande, Bull.* **35**, 1913, p. 22.

[57] Ziegler, Victor, The differentiation of a granitic magma as shown by the paragenesis of the minerals of the Harney Peak region, South Dakota: *Econ. Geol.*, **9**, pp. 264–277, April, 1914. The minerals of the Black Hills: *S. Dak. School of Mines, Bull.* **10**, 1914.

[58] Macdonald, D. P., Notes on the red feldspar of the Bushveldt tin deposits: *Trans. Geol. Soc. S. Africa*, **17**, p. 58, 1914.

Our modern concept of pegmatite crystallization was very well expressed by Galpin[59] in 1915: "After a pegmatite dike has partly or wholly formed, later magmatic solutions may come up along its walls through any cracks or openings which for various reasons may have developed in it. These solutions make a second deposit beside or in the first, resulting in a compound dike. In certain cases it seems that there are reactions between the later solutions and minerals in the pre-deposited rocks." The precipitation of a wide variety of hydrated phosphate minerals from hydrothermal solutions in the phosphate pegmatites of Bavaria was described by Laubmann and Steinmetz.[60]

McLaughlin[61] in 1919 published an account of dikes of syenite and syenite pegmatite containing chalcopyrite and bornite. In this paper the sulphides are considered to be a late product of the crystallization of the magma. They corrode the dike minerals. In his monograph on the mineralogy of Madagascar published in 1922, Lacroix[62] interprets the pegmatite cavities as products of corrosion in which were deposited later albite, tourmaline, and lepidolite.

In a paper published by J. H. L. Vogt[63] in 1926 reference is made to a lecture of Th. Vogt delivered a number of years earlier in which attention was called to the hydrothermal phase in granite pegmatites as follows: "To illustrate, there is the pure albite in druses deposited in crystallographic orientation of microcline and oligoclase; there is the muscovite in druses; there are the accompanying zeolites, etc."

Foye[64] in a paper on the pegmatites of the Middletown, Connecticut, area describes the recementation of fragments by tourmaline and apatite, which in his opinion took place through deposition by gases escaping from deep-seated sources. The concept of hydrothermal replacement was briefly suggested by Sterrett[65] in 1923 in the following words: "Some pegmatites were possibly formed in part by the intrusion of a magma and later modified by the passage of solutions from the same source." Penetration of earlier feldspars by "the end phase products, quartz and albite," is described in a paper published by Colony[66] during the same year.

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[59] Galpin, S. L., A preliminary report on the feldspar and mica deposits of Georgia: *Georgia Geol. Survey, Bull.* **30**, p. 27, 1915.

[60] Laubmann, H. und Steinmetz, H., Phosphatführende Pegmatite des Oberpfälzer und Bayerischen Waldes: *Zeit. Kryst. Min.*, **55**, p. 584, 1915–1920.

[61] McLaughlin, D. H., Copper sulphides in syenite and pegmatite dikes: *Econ. Geol.*, **14**, p. 409, 1919.

[62] Lacroix, Alfred, Mineralogie de Madagascar, *Paris*, p. 310, **1922**.

[63] Vogt, J. H. L., Magmas and igneous ore deposits: *Econ. Geol.*, **21**, p. 226, 1926.

[64] Foye, W. G., Mineral localities in the vicinity of Middletown, Connecticut: *Am. Mineralogist*, **7**, pp. 4–12, 1922.

But of outstanding importance during 1923 was the publication of two papers (written entirely in Russian) by A. E. Fersman.[67] In the first paper Fersman divides the mineralization of the nephelite-syenite pegmatites of the Kola peninsula into four phases: epimagmatic, pneumato-pegmatitic, pneumatolytic, and hydrothermal. He states: "The pneumatolytic phase is comparatively insignificant, especially when compared with the area in the vicinity of Christiania, while the hydrothermal phase is comparatively well developed and has an undoubted significance" (translated by M. K. Elias). In the second paper the origin of coronites (encrustation through substitution) is ascribed to "the action of the residual magma upon the previously crystallized minerals" (translated by M. K. Elias). A third paper published the following year[68] compares the pegmatite minerals associated with granitic magma at Mursinka, Urals, with those belonging to the nephelite-syenite intrusives of the Kola peninsula. Again the pegmatite mineralization is divisible into four phases, of which the last is hydrothermal.

The evolution of the hydrothermal replacement theory reached a peak in 1925 with the publication by five men, who worked entirely independently, of articles in which the paragenesis of pegmatite minerals is discussed in detail. Evidence is presented in each article to show that replacement is a dominant process, and the opinion is stated that hydrothermal solutions of magmatic origin are responsible for this later mineralization. The five investigators are Cook,[69] Müllbauer,[70] Hess,[71] Schaller,[72] and Landes.[73] Cook, discussing a molybdenite deposit in an alaskite pegmatite in Nova Scotia, gives the sequence of magmatic activity starting with the intrusion of the granitic country rock and ending with the deposition of tourmaline, sericite, molybdenite, and bornite in vugs. Intermediate stages include (1) injection of a pegmatite magma, (2) mineralization by magmatic waters ("residuum of the original magma") between earlier aplite and pegmatite, between the quartz and orthoclase of the pegmatite, and along cleavage planes in the pegmatitic orthoclase, and (3) sericitization and deposition of molybdenite.

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[65] Sterrett, Douglas B., Mica deposits of the United States: *U. S. Geol. Survey Bull.* **740,** p. 10, 1923.

[66] Colony, R. J., The final consolidation phenomena in the crystallization of igneous rock: *Jour. Geol.*, **31,** p. 170, 1923.

[67] Fersman, A. E., Mineral associations in the Khibinsky and Lovozersky tundras: *Bull. Acad. Sci. Russie*, series 6, **1923,** pp. 65–80; Regular intergrowths of minerals in the Khibinsky and Lovozersky tundras: *loc. cit.*, pp. 275–290.

[68] Fersman, A. E., Ueber die Natur der Pegmatitbildungen: *Compt. Rend. Acad. Sci. Russie*, **1924,** pp. 89–92. (Abs. *Min. Abstr.*, **2,** p. 399).

Müllbauer continued the work of Laubmann and Steinmetz[74] on the Bavarian phosphate pegmatites. The presence of more than one period of mineralization is emphasized in his paper. Two stages of a liquid magmatic phase were followed by a hydrothermal phase during which phospho-ferrite, lehnerite, apatite, columbite, muscovite in fine scaly masses, pyrite, sphalerite, and other minerals were deposited.

The paper by Hess on the natural history of pegmatites describes a number of instances in which replacement of one pegmatite mineral by another has taken place, drawing most of his illustrations from the pegmatites of the southern Black Hills. He also points out in vigorous fashion some of the inconsistencies in the older theories of pegmatite origin.

Schaller's paper is based on studies made by himself and E. S. Larsen of the pegmatites in the vicinity of Pala, California. He believes that graphic granite has been replaced by pegmatite minerals through hydrothermal activity. The principal evidence lies in finding "ghosts" of the graphic structure in the Pala pegmatites. The first stage in the replacement process was albitization which was accompanied or followed by muscovitization. Later, garnet and black tourmaline were formed and still later lithia minerals were deposited, replacing all of the older minerals.

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[69] Cook, C. W., Molybdenite deposit near New Ross, Nova Scotia: *Econ. Geol.*, **20,** pp. 185–188, 1925.

[70] Müllbauer, F., Die Phosphatpegmatite von Hagendorf i. Bayern: *Zeits. Krist.*, **61,** pp. 318–336, 1925.

[71] Hess, Frank L., The natural history of pegmatites: *Eng. & Mining Jour.-Press*, **120,** no. 8, pp. 289–298, Aug. 22, 1925.

[72] Schaller, W. T., The genesis of lithium pegmatites: *Amer. Jour. Sci.*, **10,** pp. 269–279, Sept. 1925.

[73] Landes, Kenneth K., The paragenesis of the granite pegmatites of central Maine: *Am. Mineralogist*, **10,** pp. 355–411, Nov. 1925.

[74] Laubmann, H. und Steinmetz, H., Phosphatführende Pegmatite des Oberpfälzer und Bayerischen Waldes: *Zeit. Kryst. Min.*, **55,** p. 584, 1915–1920.

The paper by Landes[75] discusses the detailed paragenesis of two of the central Maine pegmatites. He describes four primary periods of mineralization, of which the first was magmatic and the remaining three hydrothermal. The principal minerals belonging to the first stage are microcline, quartz, muscovite, biotite, black tourmaline, common beryl, and garnet. The second (high temperature hydrothermal) phase minerals are quartz in euhedral crystals, albite (variety cleavelandite), lepidolite, lithia tourmaline, columbite, cassiterite, spodumene, and cesium beryl. Amblygonite and rare phosphate minerals were deposited during the intermediate hydrothermal phase and quartz, cookeite, and purple apatite were formed during the final period.

Subsequent to 1925 a number of papers have been written verifying the hydrothermal replacement concept. In 1926 Schaller and Henderson[76] described replacement of pegmatite minerals in the Embudo area of New Mexico, and somewhat similar observations were made by Roos.[77] Shannon[78] described the replacement of feldspar by albite in a pegmatite in Montgomery County, Maryland.

Schaller[79] repeats his ideas on pegmatite replacement in a paper published in 1927. In this paper he carries the beginning stages back farther: "At present I am inclined to believe that the original rock formed by the magma process was a relatively fine-grained, high-temperature potassium feldspar (probably orthoclase) rock, which on cooling reverted to microcline. . . ." However, no evidence is given for this conclusion.

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[75] The inference has been made in several papers published in recent years that the writer's description of replacement in the Maine pegmatites was written after the papers by Hess and Schaller were published. The article in question was published some two months after the Hess and Schaller papers, but it was written many months before. It was accepted as a doctorate thesis at Harvard University on May 1, 1925, and was in the hands of the editor of the *American Mineralogist* when the Hess and Schaller papers appeared in print.

[76] Schaller, W. T., and Henderson, E. P., Purple muscovite from New Mexico: *Am. Mineralogist*, pp. 5–15, Jan. **1926**.

[77] Roos, Alford, Mining lepidolite in New Mexico: *Eng. & Mining Jour.*, **121**, no. 26, pp. 1037–1042, 1926.

[78] Shannon, E. V., Some minerals from the Kensington mica mine, Montgomery County, Maryland: *Am. Mineralogist*, **11**, no. 2, pp. 35–37, 1926.

[79] Schaller, W. T., Mineral replacements in pegmatites: *Am. Mineralogist*, **12**, pp. 59–63, March, 1927.

After a very detailed study of perthites occurring in granite pegmatites Anderson[80] in 1928 advanced the opinion that some perthites are due to replacement by later pegmatitic solutions. During the same year Landes[81] published another paper on pegmatites, this time describing those in the vicinity of Keystone, South Dakota. The phosphate phase is very poorly developed in this area, but there is evidence of two hydrothermal phases following the magmatic stage. The large spodumene logs of the Etta pegmatite are thought to be replacement products of the first hydrothermal phase. A. L. Anderson[82] in a paper on the tin deposits in eastern Washington states: "The minerals of the pegmatite show not only normal crystallization from solutions, but also replacement of some of those first formed. These deposits offer additional evidence that replacement in ore deposits is not confined to veins alone but can occur in pegmatites as well." Late in 1928 Pegau[83] described albitization and later replacement activity of the pegmatites in Amelia County, Virginia. A more complete discussion of the mineral paragenesis of the Virginia pegmatites was published by the same writer in 1932.[84]

During 1929 Megathlin[85] expressed a belief in the existence of several phases of mineralization in the Gilsum, New Hampshire, pegmatites, and Bain[86] described later graphite occurring in pegmatites at Louisa, Quebec.

Southwest Africa pegmatites are described by Frommurze and Gevers[87] in papers published both in 1929 and 1930 in which replacement of feldspar by albite and cassiterite is mentioned. Two generations of beryl, one of late hydrothermal age and the other "apparently the first mineral in the pegmatite to crystallize," are discussed briefly by Gedney[88] in an article published in 1930. Buddington[89] in a paper appearing during the same year describes a sequence of mineralization ranging from pegmatite crystallization to zeolite deposition in a molybdenite deposit in southeastern Alaska. Palache, Davidson, and Goranson[90] in discussing the hiddenite pegmatites in North Carolina postulate three stages of pegmatite formation: (1) lit-par-lit pegmatite stage, (2) hiddenite pegmatite stage, (3) hiddenite cavity stage. Fraser[91] applies the sequence of Landes to a pegmatite at Newry, Maine in an article which appeared late in 1930.

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[80] Anderson, Olaf, The genesis of some types of feldspar from granite pegmatites: *Norsk. Geol. Tidsskrift*, **10**, Nos. 1–2, pp. 116–205, 1928. (Abs. Annot. Bibliog. *Econ. Geol.*, **2**, 2, 507).

[81] Landes, Kenneth K., Sequence of mineralization in the Keystone, South Dakota, pegmatites: *Am. Mineralogist*, **13**, pp. 519–530; 537–558, Oct., Nov., 1928.

[82] Anderson, A. L., Genesis of Silver Hill tin deposits: *Jour. Geol.*, **36**, pp. 646–664, Oct.–Nov., 1928.

[83] Pegau, A. A., The Rutherford mines, Amelia County, Va.: *Am. Mineralogist*, **13**, pp. 583–588, Dec. 1928.

[84] Pegau, A. A., Pegmatite deposits of Virginia: *Virginia Geol. Survey, Bull.* **33**, 1932.

[85] Megathlin, G. R., The pegmatite dikes of the Gilsum area, New Hampshire: *Econ. Geol.*, **24**, 2, pp. 163–181, 1929.

[86] Bain, G. W., Graphite deposits of Louisa, Quebec: *Econ. Geol.*, **24**, pp. 733–752, Nov. 1929.

[87] Frommurze, H. F., and Gevers, T. W., *Int. Geol. Cong. 15th Session* (So. Africa) *Guide Book Excursion C 21*, **1929**. Gevers, T. W., and Frommurze, H. F., The tin-bearing pegmatites of the Erongo area, South-West Africa: *Trans. Geol. Soc. S. Africa*, **32**, (for 1929), p. 111–149, 1930. (Abs. *Min. Abstr.*, **4**, pp. 411–412; Annot. Bibliog. *Econ. Geol.*, **3**, p. 424).

A series of hydrothermal pegmatite minerals occurring at Spruce Pine, North Carolina, are described by Ross, Henderson and Posnjak.[92] Their paper was published in 1931. Later in the year a most complete exposition of the hydrothermal replacement theory as applied to the southeastern Manitoba pegmatites was published by Derry.[93] He notes the presence of both "common pegmatites" which contain only potash feldspar, quartz, micas, and sometimes black tourmaline, and "complex pegmatites" in which hydrothermal solutions have deposited albite, cassiterite, lepidolite, spodumene, tantalite, beryl, tourmaline, and other minerals. Derry also discusses the relationship of albite and tin veins to pegmatites.

Kusnezova[94] has recently described the paragenesis of pegmatite minerals in western Georgia (Transcaucasia). The pegmatites are zoned between margins and center, and the presence of pneumatolytic and hydrothermal minerals is noted. Piatnitsky,[95] working in the Urals, developed a genetic classification of pegmatites which is given in a subsequent chapter. His "polyphasic" pegmatites are described as follows: "Their body is composed of the consolidated liquid magma yet in this body there remain free spaces and pockets which subsequently are coated or filled with pneumatolytic and hydrothermal minerals." The writer is not in accord with Piatnitsky's conception of the origin of pegmatite cavities, but his ideas on cavity filling are in accord with the modern trend.

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[88] Gedney, E. K., Beryllium ores in New England: *Am. Mineralogist,* **15,** p. 120, 1930.

[89] Buddington, A. F., Molybdenite deposit at Shakan, Alaska: *Econ. Geol.,* **25,** 197–200, 1930.

[90] Palache, Charles, Davidson, S. C., and Goranson, E. A., The hiddenite deposit in Alexander County, North Carolina: *Am. Mineralogist,* **15,** pp. 280–302, 1930.

[91] Fraser, H. J., Paragenesis of the Newry pegmatite, Maine: *Am. Mineralogist,* **15,** pp. 349–364, 1930.

[92] Ross, C. S., Henderson, E. P., and Posnjak, E., Clarkeite; a new uranium mineral: *Am. Mineralogist,* **16,** pp. 114; 213–220, 1931.

[93] Derry, D. R., The genetic relationships of pegmatites, aplites, and tin veins: *Geol. Mag.,* **68,** no. 808, pp. 454–475, Oct. 1931.

[94] Kusnezova, E., Materials for the study of pegmatite veins of the Dzirul Massif. Transcaucasia: *Bull. United Geol. and Prosp. Service, U.S.S.R. L. Fascicle* **98,** pp. 1–19, 1931.

Conclusions. The lateral secretion theory as applied to pegmatites has long been abandoned. Reasons for doubting the applicability of the selective solution theory have been stated. There remains the various modifications of the igneous theory. The writer believes that enough evidence has been amassed to cause acceptance of the hydrothermal replacement theory. However, he believes that in most pegmatites (but little studied because of small size and lack of unusual minerals) a distinctly later hydrothermal phase is absent. These are the "common pegmatites" of Derry[96] and the "simple pegmatites" of this paper. The change in nomenclature is made in order to better contrast this type of pegmatite with the "complex pegmatites" in which mineralization by hydrothermal solutions has taken place. The writer's ideas on pegmatite genesis are briefly given in the following paragraphs.

Pegmatites are a by-product of the crystallization of large bodies of intrusive magmas. The minerals forming during this period of magmatic crystallization do not contain appreciable amounts of water and the other "mineralizers" or "fugitive elements." These become concentrated in the residual magma, a part of which may escape and form pegmatites either in already solidified portions of the parent body or in adjacent country rock. This "pegmatite magma" is naturally more aqueous than the original magma, but it does not approach the degree of attenuation of hydrothermal solutions. It crystallizes in a manner similar to that of an ordinary body of magma, but because of its content of volatile materials the freezing point is lower and coarser crystals will form. Furthermore the degree of reaction between the first minerals to form and the surrounding liquid will be greater than in the less aqueous magmas. Thus albite will penetrate older microcline, producing perthite (the deuteric perthite of Alling[97]), and quartz rods will form in perthite, producing graphic granite.[98] Evidence of both of these late magmatic replacements in the rare earth pegmatite of Llano County, Texas, has recently been described.[99]

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[95] Piatnitsky, P., Geological explorations in the emerald district in the Urals: *Trans. Geol. & Prosp. Service, U.S.S.R. Fascicle* **75**, pp. 1–71, 1932.

[96] Derry, D. R., The genetic relationships of pegmatites, aplites, and tin veins: *Geol. Mag.*, **68**, no. 808, pp. 454–475, Oct. 1931.

With the consolidation of the pegmatite magma the mineralization of the simple pegmatites ceases. The mineralogical character of the simple pegmatite depends upon the composition of the original magma (granitic, syenitic, etc.). The complex pegmatites owe their character to further mineralization by hydrothermal solutions, which dissolve older minerals and precipitate new ones. In some pegmatites this is a long-drawn out process, during which the chemical character of the solutions change so that earlier hydrothermal minerals become unstable and are themselves attacked and replaced. In the larger pegmatites the channelways followed by the solutions do not cover the entire pegmatite, and consequently the hydrothermal minerals are restricted to certain "bands" or "shoots" in the deposit. In some instances the solutions entirely escape from the primary pegmatite and deposit minerals in the country rock. This may explain the lack of hydrothermal activity in the simple pegmatites; the hydrothermal solutions find channelways other than through the primary pegmatite which they prefer to follow.

The immediate source of the hydrothermal solutions may be the original magma, which continues its crystallization after the expulsion of the pegmatite magma. This theory is well stated by Merwin:[100] "(pegmatites) have compositions and structures which have led to the conception that they have been derived from a residuum, or from successive residua, of cooling granite magma. These residua become increasingly hydrous, and enriched in a variety of compounds, which, because of high solubility in the liquid, or slight original concentration, have remained in solution until cooled by intrusion. . . . Reopening of the fissures after periods of cooling allows successive invasions of liquids, each in general presumably cooler than the preceding, and thus in a state of saturation ready to deposit new compounds or to dissolve or react with and replace existing minerals." However, the writer believes that in the larger pegmatites it is quite possible that the hydrothermal solutions are residua of the crystallization of the pegmatite magma itself. At Keystone, South Dakota, the four large pegmatites (Etta, Hugo, Peerless, and Ingersoll) are undoubtedly offshoots of the same parent magma. Each one contains hydrothermal minerals. It is more plausible to believe that the sources of these solutions were deeper-seated portions of each pegmatite than that later solutions from the very much deeper parent igneous body (probably the Harney Peak stock) divided and followed the same pathways that the original pegmatite magmas followed.

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[97] Alling, H. L., Perthite: *Amer. Mineralogist*, **17**, No. 2, p. 54, 1932.

[98] Vogt (Vogt, J. H. L., The physical chemistry of the magmatic differentiation of igneous rocks: *Skrifter utgitt av Det Norske Videnskaps-Akademi i Oslo, I-Mat.-Naturv. Klasse*, No. 3, second half, **1930**) in describing Fersman's determination of the parallelism in graphic granite between the edge of the unit rhomb of the quartz and the *c* axis of the feldspar, states that this condition is due to the lattice texture of the quartz and feldspar and may be explained only by "a simultaneous crystallization of both minerals." The writer believes that replacement also may be controlled by the lattice structure of the host and guest minerals so as to produce graphic textures.

[99] Landes, Kenneth K., The Baringer Hill, Texas, pegmatite: *Amer. Mineralogist*, **17**, *ppl* 381–390, 1932.

[100] Merwin, H. E., Some associations of ore minerals: *Am. Mineralogist*, **16**, *pp.* 93–96, 1931.

Fersman[101] finds that the replacement theory harmonizes with his geochemical studies: "Die 'Replacement' Theorie der amerikanischen Schule bekommt durch diese theoretischen Angaben ihre Erklärung und der Verdrängungsvorgang soll somit als eine theoretisch bedingte Folgerung des Pegmatitprozesses betrachtet werden, besonders in den weit fortgeschritten Phasen des Prozesses" (p. 213).

The hydrothermal replacement theory is also supported in part by recent geophysical investigations. Shepherd[102] has determined that water composes 80 per cent of the volatile material pumped out of Hawaiian lavas when heated in vacuo. Goranson[103] has recently determined that water may be present in natural rhyolite glasses up to 8 and even 10 per cent. A magma of batholithic proportions containing as little as 2 per cent water would have an enormous amount available for hydrothermal activity.

[101] Fersman, A. E., Zur Geochemie der Granitpegmatite: *Min. Petr. Mitt.* (Tschermak), **41,** pp. 200–213, 1931.

[102] Shephard, E. S., The present status of the volcano-gas problem: *Nat. Res. Council, Bull.* **61,** pp. 259–263, 1927.

[103] Goranson, Roy, The solubility of water in granite magmas: *Amer. Jour. Sci.* (5), **22,** pp. 481–502, Dec. 1931.

The geophysicists are not in complete agreement as to whether or not intrusive igneous activity may be accompanied by a gaseous phase. Morey[104] believes that "critical phenomena are never shown by the saturated solutions formed by the cooling magma. . . ." As far as the pegmatites are concerned the field evidence favors Morey's view, for effective replacement necessitates the presence of solutions to carry away the dissolved material.

(To be continued)

[104] Morey, G. W., Relation of crystallization to the water content and vapor pressure of water in a cooling magma: *Jour. Geol.*, **32**, p. 295, 1924.

A SECOND STONY METEORITE FROM NEBRASKA

H. H. Nininger, *Denver, Colorado.*

In December 1930 the Colorado Museum of Natural History received from Mr. E. W. Black of North Loup, Nebraska, a small sample of a stony meteorite which was said to have been found near Cotesfield, Nebraska, about two years previously. This location at once aroused our interest for the reason that only one aerolite had previously been recorded from that state, namely the Culbertson stone which location is 140 miles southwest of Cotesfield.

The nature of the Cotesfield stone had not been suspected by the finder at first, but its peculiar shape and weight had aroused his curiosity so that he preserved it among some Indian relics which had been the object of his search at the time the stone was found.

The aerolite was purchased by the museum and at the time of its arrival it was complete just as when found, except for the small sample which had been detached and sent in for our examination. Its weight was 2 lbs. 9 oz. or 1160 grams. This stone possessed one very striking characteristic as to form which at once impressed the observer. Its base was almost a perfect plane (Fig. 1), due apparently to the splitting of a larger mass along a cleavage plane, the nature of which it was thought could be determined by cutting the specimen.

The remaining features of its form can best be described by referring to the figures. The entire surface, excepting the base, was coated with a thin fusion crust which was badly discolored by a brown oxide. The base appeared to have been only briefly exposed to the heat of friction after the fracture for no evidence of fusion could be found upon it, save only a very slight ridge which seemed to result from a small amount of fused matter creeping over its edge. About half of the surface of the specimen was quite strongly pitted in the manner common to stony meteorites, while one side completely lacked these pits and appeared to be the remains of a former spheroidal mass. Here too, the crust appeared to be a bit thicker than in other places.

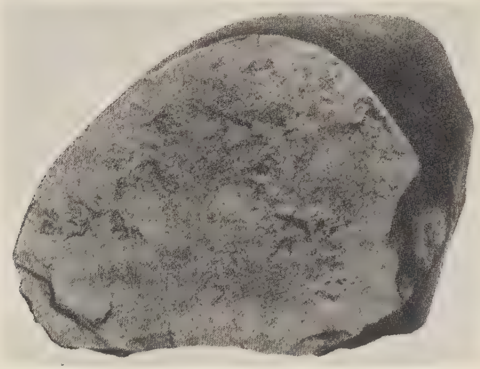

FIG. 1. A basal view of aerolite showing almost plane surface which appears to have been exposed by a break shortly before landing.

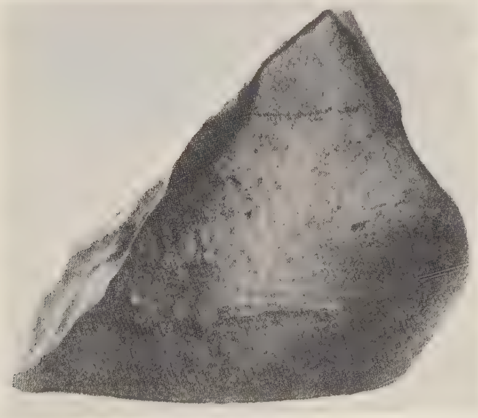

FIG. 2. View of aerolite showing primary fusion crust.

A cast was made of the specimen after which several thin slices were cut from it. Cutting proved the stone to have a compact texture and revealed a rather sparce sprinkling of metallic grains of varying size, ranging from microscopic to as much as 4 mm. in their greatest diameter. A more generous supply of sulphide grains were observed which were somewhat smaller than the metallic particles.

The stony matrix appears dark brown for the most part with irregular patches of a much lighter color; but oxidation has evidently progressed too far for any definite conclusions as to the original coloration. There seem to be evident traces of an abundantly chondritic structure but the staining from the oxides makes their study under a hand lens unsatisfactory.

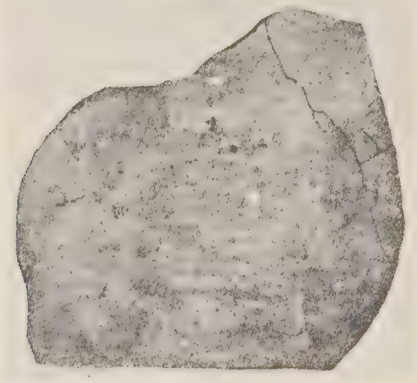

FIG. 3. A slice of Cotesfield aerolite. The white spots represent nickel-iron grains.

The most conspicuous feature of the polished slice is its veining. Broad black lines traverse several of the slices in succession reaching a maximum width of 1.7 mm. These wide portions are, however, frequently interrupted by sections which are very narrow so that the vein may seem to end bluntly.

Examinations of the cut sections did not answer satisfactorily the question as to the cause of the almost perfect parting which resulted in the present base of the aerolite; but if one assumes the existence of one of the larger veins occupying that plane, then this would nicely explain such a break. However, in no observed case did a vein follow so direct a course over such a large area as that represented by the basal cleavage surface. But since there is a noticeable tendency for the veins to run parallel to this basal plane it may perhaps be reasonably conjectured that the break was occasioned by such a vein.

No petrographic analysis has yet been made and such an analysis will be very difficult by reason of the degree to which oxidation has advanced.

The meteorite shall be known as Cotesfield, the location of which is Lat. 41°, 20′ N.; Long. 98°, 40′ W. The largest mass is in the collection of the Colorado Museum of Natural History.

A TEPHROITE CRYSTAL FROM FRANKLIN FURNACE, NEW JERSEY

Waldemar T. Schaller, *Washington, D. C.*

An excellent clear pink tephroite crystal, several millimeters long, on typical material from this locality, was measured at the request of the late Col. Washington A. Roebling. The crystal was very brilliant and showed seventeen forms, of which four are new.

The forms noted, with their measured and calculated angles, are shown in the table below. The four faces of the unit pyramid gave excellent reflections and as the crystal was readily adjusted accurately in polar position, the axial ratio was calculated from these measurements, which were:

	°	′		°	′
ϕ	65	13	ρ	54	34
	65	13		54	32
	65	16		54	30
	65	11		54	34

The average values for the axial ratio, calculated from these angles, gives:

$a=0.4616$ $c=0.5885$ $p_0=1.2748$

The measurements of the other forms, which gave fairly good reflections, gave values very close to those derived from the measurements of the unit pyramid, as can be seen by comparing the measured and calculated angles. The axial ratio obtained is in close agreement with previously determined values, which are here given:

	a	*c*
Sjögren	0.4600	0.5939
Flink	0.4621	0.5914
Gordon	0.4606	0.5899
Schaller	0.4616	0.5885

References: Sjögren: *G. För. Förh.*, vol. **6**, p. 539, 1883.
Flink: *Ak. H. Stockh.*, Bihang, vol. **13** (2), No. 7, p. 64, 1888.
Gordon: *Proc. Acad. Nat. Sci.*, Philadelphia, vol. **74**, p. 107, 1922. Corrections given in *Amer. Mineralogist*, vol. **8**, pp. 33–34, 1923.

FORMS AND ANGLES ON TEPHROITE CRYSTAL, FRANKLIN FURNACE, N. J.

$a=0.4616$ $c=0.5885$ $p_0=1.2748$

Form	Measured				Calculated			
	ϕ		ρ		ϕ		ρ	
	°	′	°	′	°	′	°	′
a(100)	90	01	90	00	90	00	90	00
b(010)	0	02	90	00	0	00	90	00
c(001)	—	—	0	01	—	—	0	00
m(110)	65	13	90	00	65	13	90	00
s(120)	47	18	90	00	47	17	90	00
r(130)	35	51	90	00	35	50	90	00
**i*(023)	0	00	21	35	0	00	21	25
h(011)	0	00	30	32	0	00	30	29
k(021)	0	00	50	14	0	00	49	39
d(101)	90	01	53	15	90	00	51	53
**v*(102)	90	01	34	36	90	00	32	31
e(111)	65	13	54	33	65	13	54	33
**g*(212)	78	41	52	10	77	00	52	37
q(122)	47	22	40	53	47	17	40	57
f(121)	47	44	60	40	47	17	60	03
l(131)	35	51	65	15	35	50	65	21
**w*(133)	35	53	36	07	35	50	35	59

The new brachydome *i*(023) is present as medium size faces (meas. $\rho=21°\,43'$, $21°\,27'$).

The new macrodome *v*(102) occurs as medium size triangular faces, dull as if etched, giving no reflections. The position was determined by its maximum brightness.

The new pyramid *g*(212) was observed once as a line face, between *d*(101) and *e*(111).

The new pyramid *w*(133) was observed four times as line faces giving poor reflections, between *h*(011) and *e*(111). The measurements are:

	°	′		°	′
ϕ	35	44	ρ	35	44
	35	44		36	17
	35	58		36	20
	36	04		36	06

The basal pinacoid *c*(001) was noted by Flink as a large face occurring on several crystals. On the crystal here described, it forms a medium sized rectangular face giving a good reflection.

The pyramid *q*(122), first recorded by Gordon, was noted twice as small faces, yielding fair reflections. The measurements are:

	°	′		°	′
ϕ	47	21	ρ	40	42
	47	22		41	03

OBSERVANCE OF CRYSTAL FORMS ON TEPHROITE.

Form	Observer				
	Sjögren 1883	Flink 1887	Flink 1916	Gordon 1922	Schaller
a(100)	*a*	*a*	*a*	*a*	*a*
b(010)	—	*b*	*b*	*b*	*b*
c(001)	—	—	*c*	—	*c*
ψ(160)	—	ψ	ψ	—	—
y(150)	—	—	*y*	—	—
z(140)	—	—	*z*	—	—
j(270)	—	—	—	*j*	—
r(130)	—	*r*	*r*	*r*	*r*
s(120)	*s*	*s*	*s*	*s*	*s*
τ(580)	—	—	τ	—	—
m(110)	*m*	*m*	*m*	*m*	*m*
x(10.9.0)	*x*	—	—	—	—
σ(210)	—	σ	σ	—	—
ρ(310)	—	—	ρ	—	—
d(101)	—	—	*d*	*d*	*d*
v(102)	—	—	—	—	*v*
i(023)	—	—	—	—	*i*
h(011)	*h*	*h*	*h*	*h*	*h*
k(021)	—	—	*k*	*k*	*k*
u(031)	—	—	*u*	—	—
l(131)	*l*	*l*	*l*	*l*	*l*
f(121)	*f*	*f*	*f*	*f*	*f*
e(111)	*e*	*e*	*e*	*e*	*e*
w(133)	—	—	—	—	*w*
q(122)	—	—	—	*q*	*q*
g(212)	—	—	—	—	*g*
t(371)	—	*t*	—	—	—

The observance of the 26 forms (including the form $u(031)$ noted by Flink without measurement) known for tephroite are given in the preceding tabulation.

The form (371) was given by Flink (1887) without letter. The letter t is here assigned to this form. These clear pink tephroite crystals represent very nearly the pure manganese silicate, as evidenced by the analysis given by Palache,[1] and the various properties determined on this material are the best available for tephroite.

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[1] Palache, Charles, Mineralogical notes on Franklin and Sterling Hill, New Jersey: *Amer. Mineralogist*, vol. **13**, p. 325, 1928.

CHEMICAL COMPOSITION OF LEUCOXENE IN THE PERMIAN OF OKLAHOMA[1]

Fay Coil

The physical and optical properties of leucoxene, the most common alteration product of ilmenite, have been described but apparently no definite information regarding its chemical composition has been available. Most investigators agree that it is an alteration product of ilmenite, although its occurrence and character may vary somewhat in different formations.

Gümbel,[2] in 1874, was the first to describe the substance as he found it in diabase and named it leucoxene. However, he thought it was a primary constituent of the rock.

An analysis made by Cathrein,[3] in 1881, of aggregate material, apparently erroneously referred to as leucoxene, gave a composition of: SiO_2 33.26, TiO_2 41.12, and CaO 25.62. It seems that the material analyzed was essentially titanite. From this analysis, apparently, subsequent writers have thought that leucoxene is a variety of titanite.

Iddings[4] states that the substance has been considered by various observers as equivalent to titanite ($CaTiSiO_5$), anatase (TiO_2), and even siderite ($FeCO_3$). He believed that leucoxene forms at the expense of ilmenite and is often pseudomorphic after it.

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[1] Abstract of thesis presented for the M.S. degree in geology, University of Oklahoma, June, 1932.

[2] Die Paleolith Eruptivgesteine der Fichtelgebirges, 22, **1874**.

[3] *Zeit. Kryst.* **6**, 244, 1881. Quoted from Zirkel. F., Lehrbuch der Petrographie, vol. 1, p. 423.

[4] Iddings, J. P., Translation of Rosenbusch, Microscopic Physiography of the Rock Forming Minerals, pp., 167–168, **1893**.

Milner[5] probably gives the most complete description of the physical and optical properties of leucoxene, but he is doubtful about its chemical composition. He states that in sediments leucoxene occurs as an alteration of ilmenite, formed largely "in situ" and is at a maximum in coarse sediments. All grains of the substance are translucent to opaque in transmitted light, and white to yellowish white ("unglazed porcelain appearance") in reflected light. The surface of most grains appears rough by microscopic pits. He gives the specific gravity as varying from 3.5 to 4.5.

In a recent paper McCartney,[6] in describing the leucoxene in the Chester sandstone of Indiana, found the substance gave no x-ray pattern, but due to the small size of the sample, he did not consider the lack of a pattern as sufficient proof of its amorphous character. He found grains of ilmenite partly altered to leucoxene, with the leucoxene in turn altered to brookite and possibly to anatase.

The leucoxene in the red sandstones of the Permian of Oklahoma is apparently similar to that found elsewhere. Its common associates among the heavy minerals are: zircon, tourmaline, ilmenite, staurolite, garnet, hypersthene, chlorite, muscovite, hornblende, rutile, anatase and ferric oxide. The light minerals are mainly quartz and feldspar, the latter forming 10 to 30 per cent of the sand portion of the sediment. Barite, invariably authigenic, is abundant in some localities in the Permian. The substance, leucoxene, is by far the most common and abundant "heavy mineral" in the Permian sandstones as shown by studies carried on by graduate students in the department of geology at the University of Oklahoma.

Of the heavy minerals of the Stillwater formation Brown[7] finds about 51 per cent to be leucoxene, in the Wellington formation

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[5] Milner, H. B., Sedimentary Petrography, 2d. ed., p. 205, **1929**.

[6] McCartney, G. C., A Petrographic Study of the Chester Sandstone of Indiana, *Jour. Sed. Petrology*, vol. **1**, no. 2, pp. 82–90, **1932**.

[7] Brown, Levi S., Unpublished thesis, Univ. of Okla., **1928**, p. 46. See also, The occurrence of leucoxene in some of the Permian Mid-Continent Sediments, *American Mineralogist*, vol. **13**, p. 115, 233.

57 per cent, and in the Garber formation 68 per cent. The average ilmenite content of these three formations is about 2.5 per cent.

Sampson,[8] in samples from the Duncan, Chickasha, Dog Creek, Whitehorse, Hennessey, Garber, Wellington, and Stillwater formations finds the heavy minerals to contain an average leucoxene content of 49.7 per cent, and of ilmenite 9.7 per cent.

North of the area covered by Sampson, Spencer[9] finds the average content of leucoxene to be about 50 per cent and of ilmenite 7 per cent of the heavy minerals. These percentages were determined on 69 samples taken from the Wellington, Garber, Stillwater, Hennessey, Duncan, Whitehorse, and Quartermaster formations.

From this it seems that leucoxene is common throughout the Permian. Since no radical differences in physical and optical properties have been noted, it is assumed that samples from any of the formations mentioned would furnish leucoxene that will be representative of the Permian. On this assumption the Garber sandstone was chosen to furnish samples. The samples were collected from an outcrop of this formation, seven and one-half miles east of Norman, the rock exposed being a buff-colored, cross-bedded sandstone, well indurated and fairly free from iron oxide stain.

After crushing about 15 kilograms of the rock the heavier material was concentrated by panning. This concentrate was boiled in dilute HCl, dried and screened. From the material which passed the 100-mesh screen, but rested on the 200-mesh screen, the heavy minerals were extracted by using bromoform as a separatory liquid. In this way about 10 grams of heavy minerals were collected. The ten grams were given further treatment, using Clerici solution as a separatory liquid, until the final sample, mainly leucoxene, weighed slightly more than one gram and had a density of 3.65 to 4.005. Under the microscope it was seen to contain considerable quartz, about 20 to 25 per cent, and some hematite (stain), and ilmenite, attached to the characteristic leucoxene.

Qualitative and quantitative analyses were made of this material. For the latter, two samples were treated in order to check results. The average of these results was as follows:

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[8] Sampson, Edw. W., Unpublished thesis, Univ. of Okla., **1929**, p. 40.

[9] Spencer, Marie, Unpublished thesis, Univ. of Okla., **1930** pp. 42–54.

	TiO_2	72.12
	SiO_2	24.49
	Al_2O_3	0.00
	Fe_2O_3	0.50
	FeO	1.35
	CaO	0.00
	MgO	0.00
	H_2O	1.66
Total		100.12

No CaO, MgO, or Al_2O_3 were present in the sample.

It was assumed that the iron was in the sample as impurities of hematite and ilmenite. The SiO_2, estimated as quartz under the microscope and determined chemically, was also assumed as an impurity. These assumptions leave only titanium oxide and water for the composition of leucoxene. The mineral composition of the sample is approximately as follows:

Leucoxene	$TiO_2 \cdot nH_2O$	72.20
Quartz	SiO_2	24.46
Hematite	Fe_2O_3	0.50
Ilmenite	$FeTiO_3$	2.84

Assuming the average density of quartz as 2.655, hematite as 5.1, ilmenite as 4.75, and of the sample analyzed as 3.828, the approximate density of the leucoxene would be 4.17.

SUMMARY

The so-called leucoxene, from the Permian, is a white earthy, opaque substance of varying density (by computation the approximate density is 4.17). Qualitatively the impure sample was found to contain the elements titantium, silicon, iron, and hydrogen. These elements were determined quantitatively as their respective oxides, viz: TiO_2, Fe_2O_3, FeO, and H_2O. The oxide molecules were further computed to give the compounds: leucoxene 72.20; quartz 24.46; hematite 0.50; and ilmenite 2.84. The last three minerals in the analyzed sample are considered impurities.

The optical and chemical investigation indicates that leucoxene is an amorphous, hydrous titanium oxide ($TiO_2 \cdot nH_2O$). It was apparently deposited or left as a residue from the alteration of ilmenite by carbonate waters.

ARTIFICIAL SPHERULITES

H. W. Morse and J. D. H. Donnay, *Stanford University, and Johns Hopkins University.*

When a crystalline precipitate is formed by the diffusion of reacting substances in a gelatinous medium, the result is usually an aggregate having certain definite and reproducible properties which are independent of its size. The aggregate often takes spherical form. Figure 1 is a photograph of the "spherulitic figure" of a strontium carbonate sphere between crossed nicols, produced by allowing 0.5 N sodium carbonate solution to diffuse into pure 10 per cent gelatin solution containing 0.02 N strontium chloride. Magnification 700; nearly homogeneous light; $\lambda=605$.

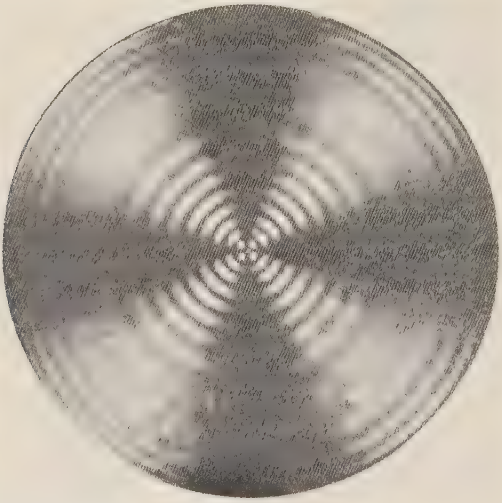

Fig. 1. Spherulite of Strontium Carbonate; x Nicols. ×700. $\lambda=605$. Photographed by H. W. Morse.

Such an aggregate is made up of a multitude of fibers radially arranged. If it is crushed it breaks along radii into acicular fragments. The indices of fragments are: $\epsilon=1.516$; $\omega=1.593$. The indices of the spherulite as a whole, measured by the method of

Spangenberg,[1] are the same as those of fibers. The spherulite is optically negative; the fibers show a corresponding negative elongation. Each fiber may be considered as a uniaxial entity, in this case optically negative, so oriented that its optic axis lies along a radius of the sphere. In polarized light, the birefringence is seen to be zero at the center of the figure and at its periphery, and a maximum at about two-thirds of the radius from the center. Although the path traversed in the aggregate is a maximum at the center, it there lies wholly in the direction of the optic axis; and while the phase difference is a maximum for unit path-length at the periphery, the distance traversed is there zero. In the figure the maximum birefringence is in the 9th order. Four decreasing orders are visible between maximum and periphery, where the others are crowded together and obscured by diffraction effects.

A discussion of the general properties of artificial spherulites and a detailed analysis of the optical properties of a spherical aggregate of strontium carbonate will be found in the *American Journal of Science*, [5], **23,** 421–461, May, 1932.

Some substances form isotropic, others anisotropic, spherulites, and the latter may be either positive or negative in character. In all the observed cases it appears that the sphere is made up of fibers and that the optic axis of each fiber lies in a radius of the sphere. Only one type of interference figure appears between crossed nicols but the insertion of a compensator proves the positive or negative character of the spherulite as a whole. As far as observation has gone there is no sign of anything "biaxial" in spherulite optics.

The sphere is only one of the many fibrous aggregate forms which can appear when precipitation of a slightly soluble substance occurs in a gelatinous medium. "Hour-glass" forms are common, as well as more complex shapes. These also are definite and can be reproduced. Maximum and minimum indices can be determined for the aggregate as a whole and these agree with the indices found for acicular fragments. It is possible to foretell the general appearance of the interference figure by means of the indices and the approximate dimensions of the aggregate.

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[1] *Centralblatt für Mineralogie,* **1920,** 408-411

THE PHOTO-LUMINESCENCE* OF ILLINOIS FLUORITE AND CERTAIN ZINC MINERALS AND ASSOCIATED SPECIES FROM THE JOPLIN, MISSOURI, DISTRICT

E. Mitchell Gunnell

Introduction

During the course of laboratory studies made at Washington University, St. Louis, Missouri, early in 1931, the writer examined a series of minerals, among which were a number of specimens of fluorite from Hardin County, Illinois, and several zinc minerals with their associated gangue species from the Joplin, Missouri, district. The object of this study was to observe such luminescence as might be activated by ultra-violet rays. The purpose of this paper is to give the results of these tests and to briefly survey some of the previous literature on the luminescence of these particular minerals.

The apparatus used to produce the activating radiation consisted of a poly-metallic carbon arc lamp housed in an insulated light-tight box, the latter being equipped with a filter-glass window placed directly in front of the arc itself. This type of apparatus is not new to investigators, a similar arrangement having been described by Andrews[1] in 1925. Eveready Therapeutic "C" carbons,[2] a poly-metallic cored type designed to produce a maximum radiation in the upper region (between 3200 and 4000 Å. units) of the ultra-violet spectrum, were employed as electrodes. A filter glass of the Corex A, UV Transmitting Red Purple type,[3] allowing passage only to wave-lengths between 2900 and 2800 Ångstrom, was used to absorb the interfering constituents of visible light produced by the arc. This apparatus operated on alternating current and proved to be both compact and efficient.

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* By "photo-luminescence" is meant either the fluorescence or the phosphorescence excited by ultra-violet rays of the particular wave-lengths employed in these tests. This infers the possibility of a specimen that is negative to one part of the ultra-violet spectrum exhibiting luminescence when exposed to another part of the same spectrum. Few investigators appear to have taken cognizance of this possibility.

[1] Andrews, W. S., The Production of Fluorescence and Phosphorescence by Radiations from the Carbon Arc Lamp. *Gen. Elec. Rev.*, **28**, 9, 659–661, 1925.

[2] Manufactured by the National Carbon Company, Inc., of Cleveland, Ohio.

[3] Manufactured by the Corning Glass Works of Corning, New York.

THE FLUORESCENCE OF ILLINOIS FLUORITE

Fluorite of two quite distinct types is obtained in southern Illinois, the massive cleavable "vein" spar mined at and near Rosiclare, and the crystallized "blanket" spar from the Spar Mountain and Crystal Mines near Cave-in-Rock. The fluorite at the former place occurs along a nearly vertical fault plane, while that at the Cave-in-Rock mines lies in closely-grouped, nearly horizontal sheets coincident with, and evidently replacing, Mississippian limestone of Chester age.[4] While occasional well-shaped crystals are met with in the fault vein workings, the bedded deposits in particular contain abundant crystals of great size and beauty of color. Some of these rival in all respects the long-famous specimens from Durham, England, seen in most mineral cabinets.

The specimens of fluorite tested were selected from a large quantity of material collected as best exemplifying the wide range in color exhibited by the Illinois occurrences. A peculiar feature observed in many crystals from the Spar Mountain Mine was the zoning of the characteristic deep violet to purple color towards the extreme outer surfaces, the interior of such crystals being devoid of colorization. The Rosiclare specimens, generally, do not show such concentration of the purple color, but evenly distributed bands of violet hue are sometimes noted in them.

No definite relationship between the colors of the crystals and their ultra-violet luminescence was here discovered. There was noted, however, a general tendency for the lighter colored specimens—colorless, white, and green—to exhibit the brightest fluorescence. Also, specimens of a blue to bluish-violet color were strongly fluorescent, being comparable both in color and luminescence to certain specimens from Weardale, Durham, England. Crystals of a yellow color gave negative results when exposed to the ultra-violet light, although hardly enough specimens of this color were tested to justify any definite statement of the invariability of this relationship.

A peculiar fluorescence worthy of record was observed in a greenish-yellow crystal from the Spar Mountain Mine. The mass of the crystal exhibited only a weak bluish fluorescence during exposure to the ultraviolet rays, but along closely grouped planes parallel to the cube $\{100\}$ faces a most brilliant yellowish-white fluorescence was observed. The fluorescence of each of these planes appeared to emanate from countless minute inclusions arranged in zones within the crystal. Specimens of fluorite with petroleum inclusions have been found at several of the mines in the Rosiclare area, notably the Hillside Mine.[5] It seemed quite probable to the writer that the fluorescence of this particular crystal might be due to such inclusions of petroleum, and in order to test this conjecture several specimens containing visible petroleum inclusions were subjected to the radiation. An identical luminescence was actually observed, the petroleum inclusions showing a bright yellowish-white fluorescence. This similar behavior would appear to justify the belief that the fluorescence of the large crystal was due to inclusions of petroleum. Engelhardt[6] examined a specimen of rock salt from Starunia in thin section under a luminescence-microscope and noted that the petroleum inclusions present exhibited a very strong yellow fluorescence.

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[4] For a complete geological description of the Illinois fluorite deposits, see Bain, H. F., The Fluorspar Deposits of Southern Illinois: *U. S. G. S., Bull.* **255**, 1905.

Although Engelhardt made the statement that organic compounds must be regarded as being responsible for the fluorescence of fluorite,[7] it would now appear, according to the recent investigation of Tanaka,[8] that in many instances the rare elements samarium, yttrium, thallium, and others, are the chief activating agents. Engelhardt's conclusion is probably true for certain specimens of fluorite, as for example the one just described, but the rare element theory seems to offer a better explanation for most fluorescent fluorites. The results of Tanaka's work is corroborated by the earlier work of Urbain,[9] who found that rare earth elements were responsible for the cathodo-luminescence of fluorite. Humphreys[10] in 1904 examined a large number of fluorites in order to ascertain the distribution of yttrium and ytterbium in this mineral, and observed that the three specimens richest in both elements were highly thermo-luminescent. Morse[11] in 1906 investigated the possible relationship of color in fluorites to optical properties, especially luminescence, and concluded that the organic substances, which at least in part cause the color, have nothing to do with the fluorescence and thermo-luminescence of this mineral.

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[5] Pough, F. H., The Fluorite Deposits of Southern Illinois and Kentucky: *Rocks and Minerals*, **23,** 7, 14–16, 1932.

[6] Engelhardt, E., Lumineszenzerscheinungen der Mineralien im ultra-violetten Licht: *Inaugural-Dissertation*, University of Jena, page. 37, 1912.

[7] *Ibid.*, page 34.

[8] Tanaka, T., On the Active Agents in Luminescent Fluorspars and in Corundum and Spinel. *J. Opt. Soc. Am. & Rev. Sci. Instr.*, **8,** 501–510, 1924.

[9] Urbain, G., Récherche des elements qui produisent la phosphorescence dans les mineraux. Cas de chlorophane, Variete de fluorine. *C. R. Acad. Sci.*, **143,** 825–827, 1906.

[10] Humphreys, W. J., On the Presence of Yttrium and Ytterbium in Fluor-Spar. *Astrophys. J.*, **20,** 266–272, 1904.

THE PHOTO-LUMINESCENCE OF CERTAIN ZINC MINERALS AND ASSOCIATED SPECIES FROM THE JOPLIN, MISSOURI, DISTRICT

The materials tested were mostly from the various mineralogical collections belonging to Washington University, and included eleven specimens of sphalerite, ten of smithsonite, eleven of hemimorphite, twenty-one of calcite, and six of dolomite. All were selected to represent the range of color, structure, and texture within each species as it occurs in the Joplin area. Although all these specimens were known positively to have come from that locality, more accurate labels than simply "Joplin, Missouri" were available for only a few of them.

Since luminescent phenomena depend upon selective absorption of ultra-violet rays and their re-emission as visible light, metallic and semi-metallic minerals which are wholly or nearly opaque to such rays cannot exhibit this property. This principle automatically disposes of the more metallic varieties of sphalerite, such as "black-jack," "steel-jack," and the like. Since most of the sphalerite mined in the Joplin district is of these dark-covered types, it was considered improbable that photo-luminescence would be observed to any high degree in this mineral. However, since luminescent sphalerites are known from several other domestic and foreign localities, there was a possibility that specimens of the light red, translucent "ruby-blende," of which magnificent specimens are common in the Joplin area, might show fluorescence. These tests, however, did not reveal a single sensitive specimen of sphalerite from this locality. Tribo-luminescence has been observed in sphalerites from many places and several of these are also known to exhibit fluorescence in ultra-violet rays.[12] Regarding the cause of

[11] Morse, H. W., Studies on Fluorite: *Proc. Am. Acad. Arts Sci.*, **41**, 585–613, 1906.

[12] Tribo-luminescent sphalerites from (1) Franklin Furnace, New Jersey, (2) Horn Silver Mine, Beaver County, Utah, (3) Mariposa County, California (phosphorescent only), and (4) Tsumeb, South West Africa. These specimens, with the exception of that from California, exhibited a brilliant orange fluorescence, while the color of the tribo-luminescence of all was an orange-red.

the luminescence of this mineral, it is well known that the white variety "cleiophane," found at Franklin Furnace, New Jersey, is generally manganiferous, and its brilliant orange-red fluorescence has been attributed to the presence of this element. Synthetic zinc sulphide has been prepared with manganese as the active ingredient, and the spectrum of its tribo-luminescence corresponded very closely with that of the natural mineral.[13] This indicates that the luminescence of certain sphalerites may be due to slight quantities of manganese, while iron—suggested as another possible active ingredient—has invariably destroyed the luminescence of synthetic zinc sulphides.[14] From the negative results of the writer's observations on the behavior of Joplin sphalerites under ultra-violet light, it would appear that the impurities present are detrimental to the production of luminescence in material from this particular area.

Smithsonite from the Joplin region proved to be in all cases except one both fluorescent and phosphorescent upon exposure to the ultra-violet light. The one inactive specimen was cavernous and highly ferruginous. The fluorescence of smithsonite was generally strong and of a white or yellow color, but in one specimen labelled "Jasper County, Missouri," it was a pale green. The phosphorescence was a pale green in all cases and while distinct, it was of very short duration. Engelhardt noted a strong greenish-white fluorescence in five specimens of smithsonite from various European localities,[15] and attributed this property to the presence of organic compounds.[16]

Hemimorphite from the Joplin district was invariably luminescent, and with only one exception—a group of white crystals from Granby—exhibited both fluorescence and phosphorescence. The fluorescence was either light yellow, bluish-white, or light green in color, and varied markedly in intensity. Specimens that fluoresced with a yellow color did so brilliantly, while the bluish-white fluorescence was invariably weak and of short duration. A white botryoidal specimen from Joplin exhibited the strongest fluorescence of any hemimorphite tested. These variations in intensity and character of fluorescence correspond quite closely with the results obtained by Engelhardt[17] on six specimens of hemimorphite from various European localities. It appears that this author includes this mineral in a series of luminescent minerals secondarily formed from aqueous solutions, the luminescence of which he believes to be due to organic impurities.

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[13] Nelson, D. M., Photographic Spectra of Tribo-luminescence. *J. Opt. Soc. Am. & Rev. Sci. Instr.*, **12,** 207–215, 1926.

[14] Mac Dougall, E., Stewart, A. W., and Wright, R., Phosphorescent Zinc Sulphide. *Trans. Chem. Soc. J.*, **111,** 663–683, 1917.

[15] Engelhardt, E., *op. cit.*, page 19.

[16] *Ibid.*, page 34.

Only six of the twenty-one specimens of Joplin calcite that were tested exhibited fluorescence, two with a strong rose color, two with an intense yellow to yellowish-white, one with a very strong orange, and one with a weak green tint. No relationship was observed between the color of a crystal and its luminescence; in fact, specimens of the yellow color generally found by Headden[18] to be phosphorescent after insolation were invariably negative to the radiation here employed. A cleavage piece of deep violet color exhibited the most intense fluorescence noted in this mineral; it was of a reddish-orange hue. The phosphorescence of these luminescent calcites was always weak, and generally of a dull white tint. Headden at first believed the luminescence of the yellow calcite from Joplin to be due to contamination by a rare earth oxide of the yttrium group[19]; later he was of the opinion that such sensitivity was due primarily to a particular atomic structure.[20] His analyses failed to detect any organic coloring matter in these calcites, thus contrasting with Engelhardt's belief that the luminescence of calcite was due to the presence of organic compounds.[21] Tanaka[22] investigated the question of the activating impurities of cathodoluminescent calcite, and stated that manganese was the chief agent, with yttrium as a less common one.

Dolomite was entirely negative. Engelhardt[23] noted a weak red fluorescence in several dolomites, a weak dark blue fluorescence in others, and a strong whitish fluorescence in specimens from Sternenberg and Mt. Vesuvius. According to Tanaka[24] manganese is the chief activating agent in cathodo-luminescent dolomite.

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[17] *Ibid.*, page 24.

[18] Headden, W. P., Some Phosphorescent Calcites from Fort Collins, Colorado, and Joplin, Missouri. *Am. J. Sci.*, **21**, 301–308, 1906.

[19] *Ibid.*, page 308.

[20] Headden, W. P., The Relation of Composition, Color, and Radiation to Luminescence in Calcites. *Proc. Colo. Sci. Soc.*, **11**, 399–434, 1923.

[21] Engelhardt, E., *op. cit.*, page 34.

[22] Tanaka, T., On the Active Agents in Luminescent Calcites, Aragonites, and Dolomites. *J. Opt. Soc. Am. & Rev. Sci. Instr.*, **8**, 411–418, 1924.

[23] Engelhardt, E., *op. cit.*, page 19.

[24] Tanaka, T., *op. cit.*, page 418.

PROCEEDINGS OF SOCIETIES

NEW YORK MINERALOGICAL CLUB

Regular Monthly Meeting of October 19, 1932,
and
Memorial Meeting for George Frederick Kunz, Ph.D.

A regular meeting of The New York Mineralogical Club was held at The American Museum of Natural History on the evening of October 19th, 1932. A familiar figure, one so familiar that it seemed almost impossible to hold a meeting of the New York Mineralogical Club without him, was missing when the members reconvened after the summer vacation. The enthusiastic youth of 46 years ago who issued the call for the first meeting of the Club, the earnest student of mineralogy, the mineral collector extraordinary, the foremost gem expert in America, Dr. George Frederick Kunz had passed away during the summer (on June 29th, 1932), and it was in his memory that this first meeting of the Club after his death was held.

Between 7 and 8 o'clock on the evening of the meeting, the Morgan Memorial Hall of the American Museum of Natural History was open to the members of the Club, where an opportunity was given them to view Dr. Kunz's collection of New York City minerals. This collection is now the property of the Club under the terms of Dr. Kunz's will and was formally transferred by The Bankers Trust Company, executors of his estate, on Sept. 30th, 1932.

The meeting was called to order at 8:30 P.M. by President Hawkins. The attendance was 76.

The minutes of the May meeting were read, corrected and approved. The Committee on Membership reported favorably on the name of Mr. Ian H. Parsons, The Wychwood, Great Neck, L. I., who was proposed for membership at the May meeting. On motion he was duly elected. Mr. J. W. Baker, R.F.D., Wrentham, Mass., was proposed for membership by Mr. Manchester and seconded by Mr. Stanton. Mr. Lucian M. Zell, 522 Fifth Ave., New York City, and Mr. Raymond S. Howell, 250 Mamaroneck Ave., White Plains, N. Y., were proposed by Mr. Stanton. These applications were referred to the Committee on Membership.

Mr. Manchester reported for the Excursion Committee that the Memorial Day, 1932, excursion of the Club to the Bedford Quarries was a success with the members arriving chiefly in autos (18 in number) and a total attendance of about 60. The Election Day excursion to Paterson Quarries will again be led by Mr. Morton and will follow the same program of a year ago.

Communications were read by the Secretary from:

American Section, Societe de Chimie Industrielle, J. Alexander, Secretary,—requesting copies of addresses, etc., on Dr. Kunz given at the Memorial Meeting to be included in a biographical note on Dr. Kunz to be sent to France. Dr. Kunz was President of this section.

Bankers Trust Company, executors of Dr. Kunz's estate—informing the Club that the title to Dr. Kunz's collection of the minerals of Manhattan Island has passed to the New York Mineraolgical Club. A legal document in evidence of same accompanied the letter.

The following reports were received and placed in the hands of the Secretary as custodian:

1931 Annual Report of the Government Mining Engineer, Union of South Africa.

1931 Annual Reports issued by Anglo American Corporation of South Africa, Ltd.

Mr. Varni called attention to the Fortieth Anniversary of the Philadelphia Mineralogical Club on Nov. 3d, 1932, and Dr. Whitlock moved that the Secretary forward a suitable resolution to the Philadelphia Club on the occasion of the Fortieth Anniversary which was so ordered.

President Hawkins began the series of addresses and reminiscences which revealed the many interests and achievements of Dr. Kunz by introducing Dr. Whitlock, who spoke on "Kunz the Mineralogist" (appended). Dr. Raymond Torrey reviewed the work of Dr. Kunz as President of the Historic Scenic and Preservation Society, and mentioned his efforts to save the Palisades which resulted in the present Palisades Interstate Park. He also advocated Nature Museums in the National Parks.

The most touching and impressive address was made by Mr. John Rosche of White Plains, N. Y., one of the eight original members present at the first meeting of the Club held in the old 23rd Street Building of The College of the City of New York, at the call of George Frederick Kunz in November, 1886. The others besides Kunz and Rosche were Washington A. Roebling, J. H. Hunt, B. B. Chamberlin, D. S. Martin, William Nevins, and B. G. Amend, then all young men just beginning their careers. Roebling became Col. Roebling of cable fame, Hunt became a distinguished physician, Nevins is a mine-owner and mineral dealer, Kunz graduated from minerals to precious and semi-precious gems, while Amend became a distinguished chemist of the well-known Eimer and Amend firm in New York City. Rosche remained a photographer but became a patron of the White Plains High School and advisor to all on the minerals of his locality.

Mr. Rothschild of the American Gem and Pearl Company gave testimony from the standpoint of a dealer in precious stones on Dr. Kunz's standing as a great gem expert and an author of authoritative works on "American Gems," "Rings," "Pearls," and the "Bischof Jade Collection." He pointed out Dr. Kunz's long connection of 51 years with Tiffany & Co. He also recalled his work in connection with the introduction of the metric system and the standardizing of the carat at 1/5 gram or 200 milligrams.

Mr. Stanton, the Treasurer, read letters from Mr. Shernikow an old member of the Club now living in San Francisco, and another letter from Mr. G. L. English, mineral expert of Ward's Natural Science Establishment who sold a collection of minerals to Thomas A. Edison which had been assembled by Dr. Kunz, the first installment of the payment of which was $5000. This was in 1888–89.

It was regularly moved and seconded that the summary of the facts and reminiscences and papers presented during this meeting shall be published as a bulletin of the Club, using for that purpose a portion of the $1000.00 bequeathed to Dr. Kunz to the Club. The meeting adjourned at 10:30 P.M.

DANIEL T. O'CONNELL, *Secretary.*

GEORGE FREDERICK KUNZ, THE MINERALOGIST

HERBERT P. WHITLOCK

One of the most impressive reactions that I carried away from the funeral ceremonies of the late Dr. Kunz was the presence of the many and varied organizations which centered there to do him honor through their most prominent representatives. I dare say that few men in our community could evince such a catholic connection of interests, or draw together such a crowd of people of distinction.

And yet, wide though Dr. Kunz's interests undoubtedly were, there was one master interest which may be said to have dominated his career, he was essentially a mineralogist, this was his first and overwhelming scientific love, and the one which he followed with zeal and success until the day of his death.

Kunz was a field mineralogist since the days of his boyhood. His early home was in Hoboken, in close proximity to the then recently opened trap rock localities at Bergen Hill and Weehawken. These openings in the New Jersey diabase proved to be a veritable mineral collectors paradise, furnishing the showy and interesting zeolite specimens which are now represented in every collection of importance throughout the world. And it was through the efforts of the Hoboken boy that many of the finest of these first saw the light and travelled to their distinguished resting places.

At this time he brought together by assiduous field work and equally assiduous exchange, his first collection of minerals, the one which he sold to the University of Minnesota. He says in his reminiscences:

"Between working days and studying nights at Cooper Union, with a few holidays in the summer, I managed to complete my first collection, and whatever also may be said of it, it was from the point of sheer bulk and weight, the most considerable I have ever made. It contained 4000 specimens, and weighed two tons." This was in 1876 when Kunz was only twenty. In three years he had made a second collection which was purchased in 1879 by the Rose Polytechnic Institute of Terre Haute, Indiana.

Seven years later, after he had become associated with Tiffany & Company as an expert in gem minerals, he became one of the founders of the New York Mineralogical Club, and was its first Secretary (at that time it had no President). Subsequently and for many years he presided over this growing organization as its President, and of the many organizations and societies of which he was at various times President, he was wont to say that he valued the Presidency of the New York Mineralogical Club the highest.

During the last two decades of the Nineteenth Century, Dr. Kunz was an enthusiastic and active collector of New York City minerals, working either alone or with William Niven, and few indeed are the excavations of that period in the rocks of Manhattan Island, which did not yield their choicest mineral specimens to his persevering hammer. The Harlem River Speedway, the Kingsbridge Ship-Canal, Inwood, and in fact all of the classic localities of our island are represented in his collection of New York City minerals now bequeathed to the New York Mineralogical Club as part of their collection. Included in this is the famous garnet crystal from Broadway and 35th Street, which measures six inches in diameter and weighs nearly ten pounds.

It is both significant and fitting that the one distinctive gem mineral of the United States should bear his name. In 1903 there was discovered near Pala, San Diego County, California, a uniquely beautiful variety of spodumene, a variety at that time known nowhere else in the world. This stone was named Kunzite by Prof. Charles Baskerville in honor of his friend and co-worker.

PHILADELPHIA MINERALOGICAL SOCIETY

Academy of Natural Sciences, Philadelphia, Pa., November 3, 1932

The Fortieth Anniversary meeting was presided over by the newly elected President, Mr. Harry W. Trudell, with 48 members and 35 visitors present. The President read congratulatory telegrams from Henry G. Ives, of Pittsfield, Mass., one of the three founders of the Society, and from the New York Mineralogical Club. Communications were also read from Mr. Howard R. Goodwin, of Columbus, Ohio, and J. Harlan Johnson of Golden, Colorado, former active members.

President Trudell then welcomed Mr. Henry Clay Borden another one of the three founders of the Society, who responded with gratification at the growth and activity of the Society since its beginning forty years ago. The Secretary read the minutes of the meeting of October 28, 1892, when Mr. Henry Clay Borden, Mr. Henry G. Ives and Mr. J. G. Richardson organized the Students Mineralogical Club. Personal reminiscences of the Society forty, thirty, twenty and ten years ago were given by Messrs. Elmer Benge, John Vanartsdalen, Dr. Edgar T. Wherry and J. C. Boyle, respectively, illustrated with lantern slides. Mr. Morrell G. Biernbaum gave a prophetic account of the celebration of the fiftieth anniversary. A number of members exhibited some of their fine specimens. The Society then adjourned for refreshments.

W. H. Flack, *Secretary.*

MINERALOGICAL SOCIETY OF GREAT BRITAIN AND IRELAND

Mineralogical Society, November 1st, Anniversary Meeting. Sir John S. Flett, President, in the chair.

Prof. H. H. Read and Mr. B. E. Dixon: *On stichtite from Cunningsburgh, Shetland.* Stichtite is found at the above locality as rose-pink patches, partly replacing chromite in a serpentine-rock. Characters determined include: $D=2.19$, refractive indices $\gamma=1.559$, $\alpha'=1.543$. Probably biaxial. Chemical analysis and discussion of earlier analyses give as the most probable formula,

$$2(\mathrm{Cr, Fe})(\mathrm{OH})_3\cdot 5\mathrm{Mg(OH)_2}\cdot \mathrm{MgCO_3}\cdot \mathrm{Mg}[\mathrm{CO_3}\cdot(\mathrm{OH})_2]\cdot 4\mathrm{H_2O}.$$

Prof. H. H Read. *On quartz-kyanite rocks from Unst, Shetland Islands, and their bearing on metamorphic differentiation.* Quartz-kyanite rocks occur as veinlike bodies in kyanite-chloritoid-schist, also as blocks scattered over the slopes. They are intimately associated with rocks much poorer in silica and richer in alumina than the normal country rock. The main component of these associated rocks is kyanite, with chlorite, and iron 'ore.' The origin of the rocks and certain general problems connected with metamorphic differentiation are discussed.

Dr. J. L. Spencer: *A new meteoric iron found near Kyancutta, South Australia.* A mass of iron weighing 72 lb. was found in June 1932 just below the surface in a sandy paddock, 28 miles E.S.E. of Kyancutta. It shows the characters of the common type of medium octahedrites, and is very similar to the numerous masses of iron found around the meteorite craters near Henbury, in Central Australia, 630 miles distant from Kyancutta.

Mr. C. A. Silberrad: *List of Indian meteorites.* The places of fall of the 106 meteorites that have been recorded in India since 1795 are located as accurately as now possible, and plotted on a map. Percentages are given for the day and night falls, and of the monthly falls.

Mr. W. Campbell Smith: *Meteoric stone from Suwahib, Arabia.* Within 30 miles of Buwah in Suwahib, where Mr. Bertram Thomas found a chondritic meteoric stone in 1931 two other stones were found a year later by Mr. Philby. They closely resemble the Buwah stone and may belong to the same shower. Sixty miles to the south a third stone was found at Umm Tina, near Shanna well. This is a chondrite of Baroti type and differs from the other two which belong to the Cronstad type.

Mr. Arthur Russell: *An account of British Mineral collectors and dealers in the 17th, 18th, and 19th, centuries* (continued). Sir Charles Lewis Giesecke. K.D. Born April 6, 1761 died March 5, 1833, was christened Johann Georg Metzler. Wrote the libretto of Mozart's "Magic Flute" (1791) also other operas. In 1794 he began the serious study of mineralogy and travelled extensively. Later he settled in Copenhagen. In 1806 he undertook a mineral collecting trip to Greenland and remained there seven years, amassing a large collection. The specimens collected during the first two years were captured by an English frigate on their way to Denmark, and were brought to Leith, where they were bought by Thomas Allan. On his return from Greenland in 1913 Giesecke landed at Leith and traced his collection to Allan, with whom he became very friendly. In 1814 he was appointed Professor of Mineralogy to the Royal Dublin Society, which position he held until his death.

Mr. Arthur Russell: *Note on an occurrence of witherite at the Morrison North Pit, Stanley, Co. Durham.* Pure massive witherite fills a fault fissure cutting coal at this pit.

Mr. M. H. Hey and Mr. F. A. Bannister: *Studies on the zeolites,* Part IV. Ashcroftine (Kalithomsonite of S. G. Gordon). The pink zeolitic mineral described by S. G. Gordon in 1924 as a potassiferous thomsonite (kalithomsonite) is shown by X-ray and optical data to be an independent species in no way related to thomsonite, and the name Ashcroftine is proposed for it. Ashcroftine is tetragonal with cell-sides $c=17.49$, $a=34.04$Å. a unit-cell content about 40 $NaK(Ca, Mg, Mn)Al_4Si_6O_{18}\cdot 8H_2O$, and D 2.61 ± 0.05. The refractive indices (ϵ 1.545, ω 1.536) are much higher than those of artificial potassiferous thomsonites, and the optic orientation is different.

Miss W. C. A. Guthrie and Dr. Christina C. Miller: *The determination of rock constituents by semi-micro-methods.* The ordinary course of the analysis of an igneous rock can be very considerably expedited by the use of smaller amounts of material throughout, the necessary accuracy of weighing being attained by means of a microbalance. Numerous experiments show that such a procedure is reliable and involves no loss of accuracy.

NEW MINERAL NAMES

Legrandite

Julien Drugmen and Max H. Hey: Legrandite, a new zinc arsenate. *Mineral Mag.*, **23**, 175–178, 1932.

Name: In honor of Mr. Legrand, who collected the mineral.

Chemical Properties: A hydrous arsenate of zinc: $Zn_{14}(AsO_4)_9OH \cdot 12H_2O$. Analysis: As_2O_5 42.02, ZnO 46.68, Fe_2O_3 2.14, MnO 0.05, H_2O 9.36. Sum 100.25.

Crystallographical Properties: Monoclinic. Habit prismatic. $a=1.6075$, $c=1.2886$, $\beta=75°35$, (from x-ray data). Unit cell dimensions: $a=12.70$, $b=7.90$, $c=10.18$Å.

Physical and Optical Properties: Color canary yellow to almost colorless. Pleochroic. G. 4.01 ± 0.05.

Biaxial positive. $2E=65°\pm5°$. Dispersion distinct, $r<v$, $\alpha=1.675$, $\beta=1.690$, $\gamma=1.735$. (all $\pm$ .005).

Occurrence: Found as massive radiating prisms on massive sphalerite with pyrite, mimetite(?), siderite(?) from the Flor de Peña mine, Lampazos, Nuevo Leon, Mexico.

W.F F.

Braggite

F. A. Bannister: Determination of minerals in platinum concentrates from the Transvaal by x-ray methods. *Mineral Mag.*, **23**, 198–201, 1932.

Name: In honor of Sir William H. Bragg and Prof. W. L. Bragg, pioneers in the x-ray investigation of crystals.

Chemical Properties: A sulfide of platinum and palladium with some nickel: (Pt, Pd, Ni)S. Analysis: Pt by difference 58.2, Pd 18.1, Ni 4.7, S 19.0.

Crystallographical Properties: Tetragonal. Dimension of unit cell, $a=6.37$, $c=6.58$Å.

Occurrence: Found in the platinum concentrates from Rustenburg and Potgietersrust, Transvaal, associated with cooperite, laurite, sperrylite and platinum.

W.F.F.

NEW DATA

Cooperite

F. A. Bannister: Determination of minerals in platinum concentrates from the Transvaal by x-ray methods. *Mineral. Mag.*, **23**, 189–195, 1932.

Chemical Properties: Formula PtS and not PtS_2 as previously reported. Analysis (on material selected from x-ray examined material, by M. H. Hey), S 17.5, 14.3; Ni 0 1; Pt (by difference 83.0, 85.6. On carefully selected material by H. R. Adam: S 14.4, 14.36; Ni tr.; Ru and Ir. —, 0.62; Pd 2.6, 4.31; Pt 82.2, 80.26.

Crystallographical Properties: Tetragonal (not orthorhombic as reported, the measured crystal being laurite). c (from x-ray data) $=1.242$. Dimensions of the unit cell $a=4.91$, $c=6.10$Å.

W.F.F.

BOOK REVIEW

Max Bauer's EDELSTEINKUNDE, third, revised and enlarged edition, by Professor Karl Schlossmacher, Director of the Mineralogical-petrographical Laboratory of the University of Königsberg. Quarto, XIV+871, profusely illustrated with text figures and plates, many of them in colors. Bernhard Tauchnitz, *Leipzig*, **1928–1932.**

The first edition of this widely used and authoritative work was issued by Professor Max Bauer in 1896, the second in 1901. In 1928 Professor Schlossmacher published the first section of the third edition. The other sections appeared at irregular intervals. As the thirteenth and last section was issued last summer, it is obvious that four years were required to complete the revision. The new edition is considerably larger than the second.

In this brief note it is impossible to point out the many excellent features of the third edition. Suffice it to say that 297 pages are devoted to the general properties of gems. This portion also includes descriptions of practically all scientific apparatus of service in the determination of gem materials. In the next 409 pages the various gem minerals are described in great detail as to properties, occurrences, and uses. These descriptions are followed by very complete discussions of the organic gems,—amber, jet, pearl, and coral, which require 64 pages. Synthetic gems are treated in 15 pages, while 56 pages are given over to gem cutting, imitations, gem carat, and determinative tables.

The new edition is by far the best and most authoritative reference work on gem stones extant. Professor Schlossmacher has performed the arduous task of revision very successfully.

Edward H. Kraus

Teaching Fellowship in Mineralogy

A teaching fellowship in mineralogy has been established at Stanford University. This fellowship is open to graduate students who intend to specialize in mineralogy and preference will be given to those who have had one year of graduate work. The chief duty of the fellow is to assist in laboratory instruction. Not more than eight or nine hours work a week will be required. The amount of the fellowship is $750.

Application for the year 1933–34, accompanied by testimonial letters, should be made to Professor A. F. Rogers, Box 87, Stanford University, California.